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16. Abstract

A tentative catalog of dark nebulae is compiled, based on previous atlases of regions of the heavens. The various statistical functions involved with dark nebulae are evolved. The latter include the functions of distribution of dark nebulae according to galactic coordinates, apparent and true areas, weight, mass, etc. Some structural aspects of dark nebulae are also discussed. Some grouping of dark nebulae is carried out, and some possible relationships shown between these nebulae and nearby celestial objects

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THE STATISTICAL STUDY OF DARK NEBULAE[1]

D. Sh. Khavtasi

The present study is devoted to the statistical investigation of dark nebulae, and the study of some regularities which characterize them. The investigation is based on the tentative catalog of dark nebulae which we compiled. /29*

Ross and Calvert's atlas, Barnard's atlas, and other literary sources, which cover the galactic zone with galactic latitudes $b=\pm30°$ and longitudes from $\ell=0°$ to $\ell=220°$ and from $\ell=310°$ to $\ell=360°$, served as the material for compiling the catalog of dark nebulae.

The study consists of four chapters.

The first chapter contains a brief summary of investigations on the matter of studying dark nebulae. Methods for investigating dark nebulae are set forth, contemporary data are assembled on the physical, geometric, and statistical properties of dark clouds, and, at the same time, some questions are formulated which require further investigation.

In the second chapter, the methods of compiling a catalog of dark nebulae are set forth, the material is discussed, and methods of recording dark nebulae and measuring their characteristics are set forth, as is the accuracy of the conducted measurements. A list of 797 dark nebulae (tentative catalog) is given at the end of the chapter.

In the third chapter, questions concerning the structural and morphological features of dark nebulae are discussed.

Some types of dark nebulae, which are interesting from the point of view of structural features, are singled out, and they are grouped according to morphological criteria. Attention is given to some regions of the heavens in which definite regularities are observed in the configuration and orientation of dark nebulae, or a connection is suspected between dark nebulae and some nearby stars.

The fourth chapter contains a discussion and statistical analysis of dark nebulae. Regularities in the apparent distribution of dark nebulae in the heavens are studied. Distribution functions of dark nebulae are constructed according to

*Numbers in the margin indicate pagination in the foreign text.

[1]The current article is the basis of the author's Master's thesis.

the apparent and true surface areas, mass, etc.. The apparent and spatial orientation of the extensiveness of dark nebulae is studied.

The basic results of the investigation are given at the end of the study.

The subject of the present study was suggested to me by Professor Ye. K. Kharadze. During the discussion of the results of the present study, I profited from the attention and valuable advice of Professor P. P. Parenago and Professor B. A. Vorontsov-Vel'yaminov, and Ye. L. Ruskol made valuable critical comments. I want to express all my sincere gratitude to them. I am also grateful to A. F. Torondzhadze for taking part in the discussion of a number of questions associated with the present investigation.

1. Contemporary State of the Matter of Studying Dark Nebulae /30

§ 1. Introductory Remarks

The study of insterstellar matter serves threefold interests.

First, interest is naturally stimulated by this problem not only because the very fact of the existence of interstellar matter in the stellar world makes its comprehensive study necessary, but first and foremost because of the fact that interstellar matter attracts attention by the diversity of forms of its manifestation, and is promising in terms of the study of physical conditions in interstellar space.

Actually, diverse non-radiating formations, which have morphological and structural features which are not devoid of interest, are visible in photographs of the Milky Way; interstellar matter is often associated with class O-B stars, forming light, diffuse nebulae—celestial objects well-known for their wealth of occurrence, which stimulate the interest of researchers; absorption lines of interstellar origin, which indicate the participation of interstellar matter in the revolution of the Galaxy, are detected in the spectra of distant stars, etc..

Interstellar matter also draws attention from the point of view of problems of physics, since it is found in a state which is not encountered under earth conditions.

In addition to what has been said, interest in the study of interstellar matter is increasing, in connection with many new problems of astronomy and physics, which can include problems of interstellar polarization, radio waves, and even cosmic rays.

Thus, interstellar matter, which is dispersed in our Galaxy in roughly the same quantity as the stellar component, should be found in close association with the latter, and should be a participant in many processes which take place in our Galaxy.

Second, the study of interstellar matter is stimulated by the scientific and practical goals of astronomy. As is common knowledge, interstellar matter, absorbing light coming from stars, distorts the picture of star distribution in the heavens, since the matter itself is distributed non-uniformly in space. Weakening the light of stars lying beyond it, and also altering the distribution of energy in those stars' spectra, interstellar matter changes the visible brilliance and color of the stars. As a result of this, it becomes necessary to take into consideration the absorption of light in interstellar space in many problems of astronomy, during the solution of which methods based on the tabulation of stars according to visible dimensions are used, or visible dimensions and star colors are generally used. After the discovery of absorption of the light, many conclusions of galactic astronomy proved in need of revision.

In light of what has been said, it becomes evident that the study of the spatial distribution of interstellar matter, the establishment of its optical properties, and the determination of the magnitude of light absorption in different directions are a problem which has great scientific and practical meaning.

Third and finally, the problem of the study of interstellar matter is also associated with problems of cosmogony. Irrespective of the currently-existing divergence of opinions on the shape and /31
type of the matter from which stars can be formed, it would be reasonable to represent the prestellar state of the matter as interstellar matter, since we still know of no other type of matter whose evolutionary path leads to a stellar state. The comprehensive study of interstellar matter would apparently foster the notion of this picture of evolution, i.e. the mechanism of star formation. In addition, interstellar matter can prove to be not only a material for star formation, but can also be, to a significant degree, a product of their subsequent development (I had in mind the eruption of matter from hot giants [1]).

The fact that the fate of the subsequent evolution of an already "formed" star, according to some hypotheses [2], depends a great deal on whether or not it is exposed to an influence from interstellar matter should be added to what has been said. Interstellar matter also plays a primary role in cosmogonic hypotheses on the origin of the solar system. The majority of cosmogonic problems is associated with the problem of interstellar matter.

In light of all that has been said, one can maintain that the problem of the study of interstellar matter is one of the fundamental problems of modern astronomy. At the present stage of development of astronomy, this problem can be considered quite real and have great scientific interest.

Interstellar matter has been the subject of animated and many-sided study in the course of the last 25 years. By now, one can speak of many properties of interstellar matter, and it is possible to make quantitative evaluations of its properties in many cases. Our knowledge in regard to this many-faceted problem is being expanded, striving for the comprehensive elucidation of the nature and properties of interstellar matter.

First, which it is appropriate to note here, is the fact that interstellar matter is not qualitatively different from the forms of existence of matter we know. Forms of matter which are familiar to us are detected in interstellar matter, which indicates the unity of our stellar world; movement and transformation of matter are observed in it, which do not, in essence, exceed the limits of the phenomena and concepts in our galactic world which are known to us. Substances are detected in interstellar space which are known to us on earth, and there is basis to assume that there are no significantly new unknown substances in this space [3].

Matter is encountered in the most diverse forms in interstellar space. Observed there are electrons, neutral and ionized atoms, molecules, and groups and combinations of molecules, which create particles of different sizes and meteoric bodies of different dimensions.

Electrons, atoms, and separate molecules form so-called interstellar gas, and the solid particles form interstellar dust. The interaction and interrelationship between the two components of interstellar matter—gas and dust—are manifested differently in different cases. The processes occur in two directions, <u>i.e.</u> both the case of condensation of gas into dust and the evaporation of the dust take place. Celestial objects are encountered which consist chiefly of interstellar gas (planetary and diffuse nebulae), as well as objects which consist chiefly of dust (dust nebulae). However, in the overwhelming majority of cases, dust and gas are evidently interspersed, forming gas-dust clouds.

The analysis of starlight, reaching us through interstellar matter, has been the only means of studying interstellar matter until now. Light which comes from stars can be exposed to influences of a different type from interstellar matter. Neutral /32 or ionized atoms, as well as molecules, form absorption lines in the spectra of distant stars. As a function of their dimensions, dust particles can evoke both general and selective weakening of the starlight, i.e. the phenomenon of screening or scattering of light will take place.

In conformity with these phenomena, different methods of studying interstellar matter are being developed and used. The study of interstellar matter by the photometric and colorimetric methods is quite effective and fruitful. Our knowledge of interstellar matter has been basically obtained from the data of photometric and colorimetric observations. The study of the spectra of distant stars with absorption lines of interstellar origin is also an effective means. By this means, one can form an opinion on the chemical composition of interstellar gas, as well as on the movement of interstellar masses. The investigation of diffuse and planetary nebulae by direct observation is especially useful for the study of the physical nature and structure of interstellar matter.

Insofar as the subejcts of the current investigation are dark nebulae in which the dust component of interstellar matter prevails, and, on the other hand, our method of investigation is statistical, we will not establish as our purpose the setting forth of the state of the problem and the methods of studying the gas component of interstellar matter, nor the general problem of interstellar absorption. The scope of those questions is quite vast, and is set forth in studies of a different type. However, large-scale summaries, with the comprehensive interpretation of these questions, are seldom encountered. Among such studies, one can list the articles of P. P. Parenago and B. A. Vorontsov-Vel'yaminov [4,5], Becker's book [6], which, however, has had time to become noticeably obsolete, and Ye. K. Kharadze's monograph [7]. We will present further only questions which concern dark nebulae.

§ 2. Dark Nebulae

The raggedness of the Milky Way's structure became well-known to the observers of the heavens who first used telescopes; it appeared quite graphically in the very first photographs of the Milky Way. The alternation in the heavens of regions rich in stars with regions in which stars are nearly absent was accepted as fact for the first time, i.e. areas free from stars were considered actual "gaps" in the distribution of stars along the plane of the Galaxy.

The dark areas in the region of the Milky Way, which were so clearly distinguished in some areas that they were associated with the "coal sacks", attracted the attention of prominent

astronomers of the last century. Even earlier, V. Herschel had first given them serious attention and, observing them systematically, had noted that they are often located near light, diffuse nebulae. V. Ya. Struve's well-founded assumption on the existence of interstellar absorption played an important role in favor of the opinion on the reality of dark nebulae. After Barnard's first photographic studies, conducted at the end of the last century, the opinion that the dark patches in the regions of the Milky Way are a result of absorption of the light of distant stars by interstellar matter was confirmed. Then came the investigations of separate dark nebulae conducted by Wolf [8], Dyson and Melotte [9], Pannekoek [10], and others. With time, facts were accumulated which indicated the presence /33
of non-radiating dust clouds in a considerable number in our Galaxy, which, by absorbing the light of stars lying beyond them, create dark areas with an apparent deficiency of stars.

There is no longer any doubt as to the reality of the dark clouds as formations of interstellar matter. The following circumstances and facts, to which we were lead by the modern development of galactic astronomy, speak in favor of the opinion that the dark patches in the regions of the Milky Way are actually existing dust clouds.

Photometric and colorimetric observations established the existence of matter, absorbing and scattering light, which causes the reddening of stars, with this reddening being greater the further the star is located from us. The abundance of such matter in our Galaxy is an observable fact. It is quite natural that this matter manifests itself as absorbing clouds in the vicinity of the Sun as well, creating an apparent thinning of the stellar density in the clouds of the Milky Way.

Our Galaxy is not an exception in this regard, i.e. the presence of diffuse matter in stellar systems can be considered a universal phenomenon. Actually, the presence of absorbing matter is observed in extragalactic nebulae close to us; this is displayed especially clearly when the nebulae are viewed "from the side".

Extragalactic objects are not observed in the direction of dark patches, and, in general, extragalactic nebulae form a so-called "zone of avoidance", which almost coincides with the equatorial region of the Galaxy. It becomes evident that such regularity in the distribution of extragalactic nebulae and the absence of extragalactic nebulae in the direction of dark patches can be explained only by the presence of light-absorbing matter in the regions of the Milky Way.

The very forms and structures of the dark patches can give evidence in favor of the opinion on the reality of the dark clouds to some extent. Complex vortical and filamentous forms, a tendency for common orientation and grouping, long canals, some regularities in their distribution, etc., can be considered some proof of the reality of dark nebulae as formations of interstellar matter.

One examination of photographs of the Milky Way convinces us of the irregularity and discreteness of composition of interstellar matter, i.e. that interstellar matter does not represent a homogenous solid layer which fills some portion of space in our stellar system, but consists of separate, discrete clouds of different sizes and densities. Other facts also indicate this.

Numerous photometric and colorimetric investigations have shown that the magnitude of absorption changes greatly when we examine sections of the heavens in different directions, and this is detected within a single constellation, and, in some cases, in directions which differ from each other by 1-2 degrees overall. Sections of the Milky Way have been detected where absorption is almost absent up to 2000 parsecs. In addition, the magnitude of absorption often does not increase uniformly with distance, but in bounds. The study of light absorption along galactic longitudes also leads us to the conclusion that interstellar matter is distributed discretely in space.

Academician V. A. Ambartsumyan [11], V. Ye. Markaryan [12], /34
and others, having investigated fluctuations in the numbers of extragalactic nebulae and stars, arrived at the same conclusion. The effect of an increase in the mean square fluctuation in the numbers of extragalactic nebulae with a decrease in galactic latitude, discovered by V. A. Ambartsumyan, finds a natural explanation in the hypothesis on the discrete structure of interstellar matter.

Thus, it can be considered an established fact that the dust component of interstellar matter consists of separate, discrete clouds—dark nebulae of different sizes and densities.

3. Methods of Studying Dark Nebulae

The study of dark nebulae has followed three paths. Separate dark nebulae were investigated by tabulating stars, posing the tasks of studying the visible shapes and dimensions, the distance from us, and the magnitude of absorption of the light produced by a given nebula. The second path consists of combining the study of the given problem with the study of the problem of interstellar absorption, based on data obtained by the colorimetric method. Thus, physical conditions in dark clouds were studied, as well as the values of the physical and geometric characteristics of dark nebulae. And, finally, the average values of some characteristics of dark nebulae were determined, basing this on some reasonable underlying assumption on dark nebulae and utilizing the statistical method.

A simple idea <u>per se</u> lies at the basis of the method of stellar tabulation, proposed by Wolf [13]. A dark nebula, absorbing the light of stars lying beyond it, should change the dependence of the function of the number of stars N(m) on m. A curve is constructed of the function N'(m) for stars located in the region of a dark nebula, and also, for comparison, the analogous function N(m) for an adjacent "normal" region. The point and magnitude of divergence of these curves indicates the distance from us of the dark nebula and the magnitude of the light in it. The mathematical analysis of Wolf's method, given by K. F. Ogorodnikov [14], indicates the following dependence between the functions N(m), N'(m), and A(m):

$$N'(m) = N(m-\varepsilon) + \varepsilon A(m), \qquad (1)$$

where ε is the absorption of light, expressed in stellar magnitudes, and A(m) is the number of stars, the stellar magnitude of which lies in the interval $m_0 - \frac{1}{2}$, $m_0 + \frac{1}{2}$.

During the derivation of formula (1), the assumption was made that the dispersion of stars α is equal to zero, <u>i.e.</u> M= const., and this is significant.

K. F. Ogorodnikov showed that if α is not very great and we represent the function of luminosity $\varphi(M)$ as:

$$\varphi(M) = \frac{1}{\alpha\sqrt{2\pi}} e^{-\frac{1}{2\alpha^2}(M-M_0)}$$

the function N'(m) takes the form: /35

$$N'(m) = N(m-\varepsilon) + \varepsilon \cdot A(m) \int_{-\infty}^{Q} e^{-x^2} dx, \qquad (1')$$

where

$$Q = \frac{m_0 - m + M_0 - M}{\sqrt{2}\,\alpha}.$$

Formula (1') is transformed into formula (1) with α=0.

K. F. Ogorodnikov proposed his method, which is applicable with any value of dispersion α. The dependence between the functions N(m), N'(m), A(m), and A'(m) and the magnitudes of ρ_0, ε, and λ turns out to be the following:

$$\log N'(m)\left[\frac{A(m)}{N(m)} - \frac{A'(m)}{N'(m)}\right] = \log P + \log D_0 \varphi(M),$$

where

$$P = \varepsilon \cdot \omega \cdot e^{(3-\lambda)\rho_0}$$

and for a stellar density D(r), Seeliger's law is adopted:

$$D(r) = D_0 r^{-\lambda}$$

Next, ε and ρ_0 are determined, i.e. the absorption of light and the distance to the dark nebula, by means of some manipulations and based on the comparison of the curve $\log P_0 \varphi(m)$ with the curve $\log N(m)\left[\frac{A(m)}{N(m)} - \frac{A'(m)}{N'(m)}\right]$.

K. F. Ogorodnikov's method is free from those errors which are brought about by not taking the dispersion α into account. This method can be considered the best means of determining the magnitude of the absorption ε and the distance ρ_0 of separate dark nebulae[1].

The method of calculating stars has a number of shortcomings, which make the obtained results not fully accurate in some respects, like, for example: the selection of a "normal" region for comparison is more or less subjective and conditional. Thus, relative results are obtained. In addition, there is usually an insufficient number of stars on the surface of a dark nebula for averaging. Inaccuracies in stellar magnitudes and the dispersion of the stars' absolute magnitudes are sources of errors in the results.

The following circumstance should be especially noted. Tabulations of stars are conducted in certain areas, the dimensions of which are equal to 500" x 500" in the majority of cases. Therefore, the features of shape and structure of dark nebulae can be lost because of averaging. One can be convinced of this by comparing the outlines of dark nebulae, obtained by means of tabulating stars, with photographs of those same nebulae. Thus, one can conclude that the star tabulation method is not capable of revealing the fine structural features of dark nebulae. This can be especially confirmed with respect to dark nebulae of small dimensions. /36

But nevertheless, until now, the method of tabulating stars has been a widespread and fruitful means of studying separate dark nebulae. The coordinated work of some observatories—Pulkovo, Harvard, Upsalla, and others—was conducted for the purpose of studying separate vast sections of the Milky Way according to a common plan. Almost all dark nebulae accessible to observation by observatories of the northern hemisphere have

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[1]We will not dwell on the description of the many well-known modifications and improvements of Wolf's method in the literature [65], [66], [67], [68], [69], [70], [71], [72]. [73], [74], especially since they yield to Ogorodnikov's method in accuracy and simplicity of use.

been studied by the method of stellar tabulations.

Analysis of the light having passed through a dark nebula is a means of studying the physical conditions in dark clouds, since the investigations of interstellar absorption should furnish us a series of valuable data about dark nebulae. We will cite two examples in support of what has been said. The very fact of the existence of selective absorption along with general absorption indicates that there are small particles in dark nebulae which cause scattering of light. This circumstance is important during the determination of the mass, density, optical properties, and other characteristics of dark nebulae. On the other hand, it is possible to determine the most widesprea dimensions of the particles, since the nature of selective absorption, i.e. the dependence of the magnitude of absorption on the wave length λ, can be established by direct observations.

The dependence of the coefficient of absorption on distance indicates the distribution of optical thicknesses and the general nature of the change in spatial density of the interstellar clouds encountered in the path of a ray. In addition, the discreteness of composition of interstellar matter, its tendency for concentration in the plane of the Galaxy, the existence of interstellar clouds near the sun, and many other facts have been established by the method of color surplus. In a word, nearly all results obtained by the study of general and selective absorption furnish information on the dark nebulae themselves in a direct or indirect manner.

Investigations of dark nebulae, in which the statistical method is utilized, are well known in the literature. In spite of the fact that investigations of such a type can furnish us much valuable information on dark nebulae, they are encountered less frequently than others. The reason for this, it seems to us, is the absence, until now, of material on dark nebulae which is suitable for statistical investigations. Today, there is a single catalog of dark nebulae, compiled by Barnard as early as 1927. Even with all of its merits, it does not satisfy all of today's requirements. Therefore, the average values of many characteristics of dark nebulae were determined on the basis of other data, or on the basis of some assumption or other of a theoretical nature. The following paragraph will deal with these characteristics in detail.

§ 4. Characteristics of Dark Nebulae /37

We now know that interstellar matter is condensed into separate clouds, but, in view of the fact that the clouds have extremely irregular shapes and frequently are not separated from each other, the average geometric characteristics of dark nebulae acquire a somewhat conditional sense. Because of the ragged structure, local condensation or separate formations, joined to the large nebula by narrow isthmuses, can form on the periphery of a dark cloud. In our subsequent description, we will consider such local formations as separate nebulae, since, it seems to us, they can not help but play a somewhat independent role in the evolution of dark clouds.

The determination of the distance r to dark nebulae makes it possible to evaluate their geometric dimensions, since the angular dimensions of these objects can be easily measured directly. During the derivation of the average dimensions of dark nebulae, one should take into account two circumstances: first, the distances r are determined by the star tabulation methods, but these tabulations were used for large nebulae in the majority of cases, since they also attracted the attention of researchers. Second, as a result of averaging, dark nebulae of small dimensions were obliterated in the star tabulations. Thus, the selection of dark nebulae was not equally probable in the sense of their geometric dimensions.

According to earlier determinations, subsequently corrected by K. F. Ogorodnikov and O. V. Dobrovol'skii [15], P. P. Parenago [16] derived the average magnitude of the radius of dark nebulae:

$$\bar{R} = 10 \text{ parsecs} \tag{2}$$

But, in virtue of what has been said above, the value of (2) can be considered exaggerated.

P. P. Parenago [16] also evaluated $\bar{R}$ by another means. He obtained the dependence:

$$a_0 = \frac{3\pi^2}{8}\bar{\varepsilon}\varphi(0)\bar{R}^2,$$

which associates the magnitudes: a_0 — absorption per kiloparsec in the plane of the Galaxy, $\bar{\varepsilon}$ — average absorption of dark nebulae, $\varphi(0)$ — number of dark nebulae per unit of volume in the environs of the sun, and $\bar{R}$ — average radius. a_0 and $\bar{\varepsilon}$ are determined reliably from these magnitudes. Relative to $\varphi(0)$, one can assume: $\varphi(0)=7\cdot10^{-4}$ dark nebulae/parsec^3. Then, for $\bar{R}$, we obtain

$$\bar{R} = 2.3 \text{ parsecs}$$

According to P. P. Parenago, the extreme values of the radii of dark nebulae lie between 1-15 parsecs.

As we have already indicated, the dark nebulae which create the ragged structure of the Milky Way are located a great distance from the sun. The average distance, according to the data of Ogorodnikov and Dobrovol'skii, is 600 parsecs. Kreiken [18] assumes that they are located even closer—at 100-200 parsecs. According to B. V. Kukarkin [19], this distance is 150-250 parsecs. /38

An important characteristic of dark nebulae is their absorbing capacity. It is characterized by the magnitude of ε—the average absorption of light in an individual dark cloud. The magnitude of ε can be determined in several ways. One can determine it directly by the method of stellar tabulations. However, as has already been indicated, dark nebulae which are the most prominent against a background of stars, i.e. with large ε, were studied by this method. V. A. Ambartsumyan [11] obtained $\bar{\varepsilon}=0.19$ by the statistical method, according to fluctuations in the number of extragalactic nebulae. B. V. Kukarkin [21] and P. P. Parenago [22] obtained $\bar{\varepsilon}=0.34$ and $\bar{\varepsilon}=0.27$, respectively, for this magnitude. Thus, by taking the data of other authors into account as well, one can take an average value for $\bar{\varepsilon}$:

$$\bar{\varepsilon} = 0.25.$$

As we already noted, the selective nature of the absorption indicates that interstellar clouds consist of dust particles. Through the labors of many researchers, it has been established that the magnitude of the selective absorption A is inversely proportional to the wave length to the α degree, i.e.

$$A \sim \lambda^{-\alpha}.$$

Regarding α, the study of O. A. Mel'nikov [17] in 1936 established that for the photographic region of the spectrum, $\alpha=1$. Subsequently, this conclusion found corroboration in the works of other authors ([60], [61], [62], [63], and others). It should only be emphasized that α is not constant for different regions of the spectrum. Thus, only in the photographic region do we have

$$A \sim \lambda^{-1}.$$

This makes it possible for us to form an opinion about the dimensions of the interstellar dust particles. O. Struve [23], analyzing every possible dimension of dust particles, decided on the value:

$$\rho = 10^{-5}\ \text{cm}, \qquad (3)$$

rejecting all the rest for different reasons. Of course, (3) has a statistical meaning, i.e. among all of the possible particle dimensions, $\rho = 10^{-5}$ cm is encountered as the most wisespread and prevalent; besides these, there can be particles which are ineffective in the sense of light absorption, and therefore are not detectable. In the study of Ye. K. Kharadze [7], like in some other studies, by the way, there is an indication of the dependence of the magnitude of ρ on the galactic latitude. A dust environment consisting of particles with $\rho = 10^{-5}$ cm possesses a high absorbing capacity. According to the calculations of Russell [24], 0.1 mg of dust, consisting of particles with radii $\rho = 10^{-5}$ cm, is capable of weakening light by $\Delta m = 9^m$ in 1 cm^2 of cross-section.

Insofar as the validity of Mie's theory [34], [25] is recognized in regard to the scattering of light by interstellar dust particles, which is quite likely, the latter should consist of solid particles. But, we can not know whether they are mettalic pellets or crystals of ice, dielectrics, etc.. Even Mie's theory does not make it possible to unequivocally resolve the question of the chemical composition and the radii of interstellar dust particles. /39

Investigations of the density of the matter in dark nebulae, relying on different methods, leads to results which conform satisfactorily among themselves. The determinations of the density according to stellar movements, frequency of hyperbolic meteors, or, for individual dark nebulae, according to their optical thicknesses, are grouped around the value:

$$5 \cdot 10^{-24} \text{ g/cm}^3,$$

which can also be taken as the average density of the matter in the dark nebulae.

The number of dark nebulae per unit of volume, i.e. their spatial density, and the total number of dark nebulae in the Galaxy can be determined based on the study of V. A. Ambartsumyan and Sh. G. Gordeladze [26]. It turned out that a single dark nebula is encountered in a cube with a 15 parsec edge. However, the study indicated here corroborates the identity of light and dark nebulae.

If the value:

$$D(0) = 7 \cdot 10^{-4} \text{ dark nebulae/parsec}^3$$

is taken as the density of the dark nebulae in the vicinity of the sun, then, according to P. P. Parenago [28], the total number of dark nebulae in the Galaxy will be:

$$N = 10^{8}.$$

According to the evaluations of V. G. Fesenkova [29] and P.P. Parenago [22], the total mass of the dark nebulae in our Galaxy turns out to be equal to:

$$M = 10^{8} \text{ solar masses.}$$

Thus, the current values of the characteristics of dark nebulae amount to the following. Interstellar dust, having a mass equal to 10^{8} solar masses and consisting of solid particles of different magnitudes, among which particles with a radius of 10^{-5} cm prevail, forms individual dust clouds, the total number of which is on the order of 10^{8}. These clouds have most diverse shapes and differ among themselves in dimensions, masses, densities, etc.. However, the "average dark nebula" has a radius equal to 2.5 parsecs, mass equal to one solar mass, and a density of 10^{-24} g/cm .

§ 5. Statistical Functions of the Characteristics of Dark Nebulae

Dark nebulae, as is by now indisputable, are the cause of interstellar absorption. It has been established that the sharp changes in surface brightness of the Milky Way are caused by the absorption of light by the dark clouds located close to the sun. Kreiken [31] investigated this question. If ΔM were the absorption of light producible by the dark cloud, then the difference in brightnesses of the dark nebula with a normal range of Δm, expressed in stellar magnitudes, would depend on ΔM and r—the distance of the dark nebula from the observer. Kreiken gives the following dependence: /40

$$\Delta m = 2.5 \log 0.1 \left| n + (10 - n) \cdot 10^{-0.4 \Delta M} \right|, \qquad (4)$$

where n=0,1,2,...,10 correspond to different distances. With n=0, i.e. with direct proximity of the dark nebula to the observer, $\Delta m = \Delta M$, and with n=10, i.e. with $r = \infty$, $\Delta m = 0$. Kreiken compiled a table of expression (4) for values of ΔM=1.25, 5, and 10, and n=1, 2, ..., 10, and, analyzing it, arrived at the following conclusions. The effect of the absorption of light by the dark nebula in the surface brightness of the heavens Δm is a function of the distance r and the opacity ΔM. This effect decreases quickly with an increase in the distance r, and after only 1000 parsecs, it becomes identical for nebulae which differ markedly among themselves in ΔM. For dark nebulae, the Δm of which is equal to 2 or 3 stellar magnitudes, the maximum distance (i.e. with a minimal value of ΔM) falls within 100-200 parsecs. From here, Kreiken arrived at the conclusion that the dark nebulae which create sharp and marked changes in the brightness of the Milky Way should be located close to the sun—at

100-200 parsecs.

The stated conclusion also stems from the correlation, established by B. V. Kukarkin [19], between the brightness of different sections of the Milky Way and the color surplus of the stars located in the very same sections and located at a distance of 160-250 parsecs. This correlation is absent when distant stars are selected (so-called Shain's paradox [33]).

As we have already indicated, the study of dark nebulae in separate sections of the heavens makes it possible to obtain information in regard to the structure of the Milky Way. In addition, the noted structural features of the dark nebulae themselves have hitherto been an important means, which makes it possible to form an opinion about the forces acting on the dark clouds and about the possible paths of their development[2].

However, the study of many questions of stellar astronomy depends to a great extent on those data which we have available on the average values of the characteristics and on the averaged picture of the spatial distribution of dark nebulae. Therefore, the study of the statistical functions of the characteristics of dark nebulae acquire significance.

The spatial distribution of dark nebulae, i.e. knowledge of the function of density D(r), is extremely interesting. As is common knowledge, the irregularity of the apparent distribution of dark nebulae is caused chiefly by the nebulae located close to us. Therefore, it would seem that one could digress from the effect of the apparent irregularity in the procss of investigating the entire system of dark nebulae, and assume:

$$D(r) = \text{const.} \tag{5}$$

This has been done in many investigations ([31] and others). /41
However, it is impossible to recognize such simplification of the problem as satisfactory, and it is inconsistent with contemporary concepts of the sub-systems of the Galaxy. The fall in density in a direction perpendicular to the plane of the Galaxy has an exponential nature in other sub-systems, and the form for the function

$$D(r) = D(o)\,e^{-\frac{r\sin b}{\beta}} \tag{6}$$

proposed by P. P. Parenago [16] therefore seems reasonable. However, direct proof, i.e. obtained by direct calculation, of the validity of law (6) or the non-validity of (5) has not been

[2]We will touch upon these questions again in the third chapter of the current investigation.

given as yet.

By analogy with other sub-systems of the Galaxy, a generalization of expression (6) was made, which takes into account the changes in density of dark nebulae according to galactic longitude (A. S. Sharov [64]).

There is still little known in regard to the distribution function of dark nebulae according to radii, i.e. $\varphi(R)$. P. P. Parenago [22] proposed a form for this function which is similar to Maxwell's law of distribution of the moduli of velocity of gas molecules:

$$\varphi(R)\,dR = \frac{4h^3}{\sqrt{\pi}} e^{-h^2R^2} R^2 dR.$$

Kreiken [18], not having given the function $\psi(r)$ a concrete form, draws the conclusion that the average apparent radius of dark nebulae is proportional to r^{-1}, and also that the number of dark nebulae increases in proportion to r. However, an assumption is made here: $D(r)$=const.

Ye. A. Ruskol [36] investigated the distribution of regular dark nebulae according to the magnitude of compression:

$$\gamma = \frac{a-b}{a},$$

where a and b are the large and small axes, respectively, of the ellipsoid of revolution, for which a dark nebula, visible in the form of an ellipse, is taken. The function of distribution $\varphi_1(\gamma)$, which is constructed, granted, on a small amount of material (69 objects), is represented in graphic form, from which it follows that dark nebulae with large γ, i.e. more elongated, prevail. She also constructed the function of distribution according to angles of orientation ψ, i.e. $\varphi_2(\psi)$, and she arrived at the conclusion that the majority of dark nebulae is oriented along the plane of symmetry of the Galaxy.

In spite of the fact that the average value of the magnitude of light absorption by a dark nebula $\bar{\varepsilon}$ was determined repeatedly, a form of the distribution function of dark nebulae according to ε, i.e. $\varphi_3(\varepsilon)$, has not been proposed. We know that dark nebulae exist, in which the absorption of light reaches three or more stellar magnitudes, as well as nebulae which are almost transparent. The function of distribution $\varphi_3(\varepsilon)$ is evidently of great interest.

As concerns other functions of distribution of dark nebulae, for example $\varphi_4(M)$—distribution according to mass, $\varphi_5(\rho)$, distri- /42 bution according to density, etc., they have not been studied, and what is more, there has not been a reference to them anywhere at all.

Thus, one can conclude that, in spite of the great importance of the question, the statistical functions of distribution of dark nebulae have not been studied in the proper manner. In some cases, they are constructed by analogy with other similar phenomena, or according to considerations of a theoretical nature, and others—on the basis of a very small amount of material. And, in many cases, there are no indications of them whatsoever in the literature. It seems to us that the main cause of this situation is the absence heretofore of complete and uniform statistical material in regard to dark nebulae.

II. About the Catalog of Dark Nebulae

§ 1. Introductory Remarks

As has already been said in the first chapter, the dust component of interstellar matter was subjected more than once to investigations by many authors from different points of view. Because of these investigations, based on diverse methods, rather interesting information was obtained in regard to dark clouds: the values of many characteristics of individual dark nebulae were determined; interstellar clouds were allotted their definite place in a model of the Galaxy; the average statistical values of a number of characteristics were determined; a method was developed for the calculation of the absorption of light in interstellar space; different mechanisms, based on some assumptions or others, were proposed for the explanation of the processes which occur in the interstellar environment.

However, as of now, a full morphological study of the Milky Way has still not been conducted, i.e. the outlines, shapes, and borders of all observable dark nebulae have not been established, insofar as possible, while many researchers have indicated the necessity of such a study. This necessity is felt especially with the study of the structure of the Milky Way, the elucidation of the configuration of the spirals of our Galaxy, the investigation of star distribution in the heavens, etc.

Along with this, a complete list of dark nebulae was not even possible until now, although the need for it is also keenly felt.

A catalog of dark nebulae, which would include as great a number of objects as possible and be composed of homogenous material, would facilitate the study of many questions of contemporary stellar astronomy. Such a catalog would combine known data on dark nebulae, spread over various printed studies, and assemble them into a unit. In addition, it would create common numbering of dark nebulae, which has also not been done as yet, in spite of the fact that it has great significance in the sense of the completeness of subsequent investigations in the given area. By serving as material for statistical investigations, a catalog of this type would finally provide many interesting conclusions relative to the statistics of dark nebulae and their geometric, physical, and other characteristics.

All investigations carried out in this direction, even if they were not completely exacting, i.e. not relying on accurate tabulations of stars, but embracing as substantial and homogenous material as possible, seem to us timely at the current stage of study of interstellar matter and of considerable value, since any possibility of going deeper into the study of this important problem must be evaluated. /43

Through detailed examination of photographs of the Milky Way, the possibility appears of establishing the presence of dark nebulae in them, defining their shapes and borders, evaluating darkenings, determining orientation, studying structural features, etc., especially if this is done on such excellent photographs as in Ross and Calvert's atlas [37].

The stated reasons compelled us to undertake a study to compile a catalog of dark nebulae.

If such attempts were made earlier, then the researchers undoubtedly faced a series of difficulties, which were caused by the following circumstances. Good photographs of separate regions of the heavens were not completely sufficient for catalog work, and Ross and Calvert's atlas appeared comparatively recently. In addition, it was not the custom to conduct measurements on positive photographic prints, since, in the majority of cases, interest in "dark patches" was demonstrated only insofar as it was associated with the problem of interstellar absorption, for the study of which opaque photographs, i.e. photographic prints, were not used.

It should be added to what has been said that the very shapes of dark nebulae are so diverse and different in dimensions and structure, and individual nebulae are so often superimposed on each other, that the principle of dividing a dark patch into individual nebulae, and their designation and numbering, would have inevitably been quite subjective. The very fact of the existence of a dark nebula at a given point in the photograph could prove to be in doubt in many cases.

It was simplest to designate dark nebulae using the nearest bright star or to limit oneself to the indication of only the constellation to which they belong. In some cases, the designation of dark nebulae was associated with light, diffuse nebulae at the borders of which they were located. Thus, dark nebulae were designated almost randomly in nearly all investigations, and common numbering had still not been introduced.

In speaking of the fact that attempts to catalog dark nebulae had not been made as of now, we did not have Barnard's catalog and atlas in mind, for we intended to dwell on them in detail, since they are the sole attempt, as far as we know, to give a general, broad description of sections of the Milky Way for the purpose of systematization, renumbering, and establishment of structural features of dark nebulae.

We will put aside the examination of numerous atlases in which dark nebulae are mentioned along with other celestial objects. These atlases are not independent investigations: data from other literary sources are gathered in them and they are associated only with instructional manuals, or with the popularization of astronomy.

Barnard's atlas [38] appeared in 1927. It consists of two parts. 50 photographs of selected sections of the Milky Way are given in the first part, the location of the centers of which is shown in figure 1. /44

As is evident from figure 1, the photographs, each of which encompasses an area of the heavens on the average of 8° x 8°, represent quite well the sections of the Milky Way in the direction of the galactic center. There, they overlap each other, which can not be said about the remaining portion of the area of the Galaxy. The galactic zone with galactic latitudes of ±20° and longitudes from ℓ=80° to ℓ=210° are only 20% covered by the photographs. Thus, vast regions in the constellations Monoceros, Perseus, Giraffe, and Cassiopeia, as well as the well-known branching of the Milky Way from the constellation Cygnus to Serpens, are not represented at all. Thus, the photographs in Barnard's atlas do not represent the zone of the Milky Way in question sufficiently completely. Barnard evidently did not set himself the purpose of representing the entire galactic region. He chose the section richest in dark nebulae, which he also thought more interesting for the recording and elucidation of the structural features of dark nebulae.

A catalog of dark nebulae is given in the very first part of Barnard's atlas. It contains 349 objects, and gives the values of the following characteristics: number in order, equatorial coordinates, and remarks on shape, with an indication of the dimensions of the diameter of axes. The nearest other celestial objects are also noted: bright stars, star clusters, diffuse nebulae, etc..

Maps, which correspond to the photographs in the first part, are given in the second part of Barnard's atlas. The outlines of the dark nebulae are drawn on the maps, and numbers, increasing in order of direct ascension, are assigned. It should be noted that the numbering in Barnard's atlas is done insufficiently accurately. But the outlines are done with great care and are sufficiently accurate. Drawn on the maps are those dark nebulae which are clearly delineated in the photographs by their shape and blackness. Contrast in the darkening between the background and the dark nebulae is the guiding criterion for establishing the existence of a dark nebula, which is natural. But here, only those dark nebulae in which the magnitude of this contrast is great are distinguished. Thus, the majority of the dark nebulae recorded by Barnard evoke no doubt whatsoever. One can only argue whether they are independent, individual formations or a part or component of another adjacent dark patch, since, in the majority of cases, dark nebulae of small dimensions were recorded by Barnard.

However, many dark nebulae, especially those of large dimensions and low contrast, <u>i.e.</u> weakly delineated against the background of stars, are omitted in Barnard's catalog and atlas. One can cite the following example in support of what has been said. The light diffuse nebula "America" is surrounded by dark dust matter, which creates a dark patch on the photograph in which stars are almost absent. In photograph No. 46 in Barnard's atlas, this diffuse nebula is represented well and studied in detail. But the dark nebulae located to the east and west of the nebula "America" are not drawn on the map, while many small dark nebulae, globules, and even dark filaments (see dark nebulae Nos. B350, B355, and others) are recorded on it. Other examples could also be cited. /46

Thus, Barnard's catalog contains dark nebulae far from completely. As was already noted above, nebulae of large dimensions and nebulae weakly delineated in the photographs, which comprise the majority of all dark nebulae, are absent in it. In addition, since the photographs in Barnard's atlas do not overlap each other in many cases, nothing could be said about the dark patches located at the edges of those photographs.

In its time, Barnard's atlas played a significant role in the study of dark nebulae. After its appearance, few people doubted the reality of dark nebulae. It provided the possibility of investigating the structural features of these objects in detail. But it is impossible to consider Barnard's catalog a complete survey of dark nebulae, like there are different "Surveys" of stars or other celestial objects, since, we repeat, the dark nebulae located in the galactic region under investigation are far from completely represented in it. This probably

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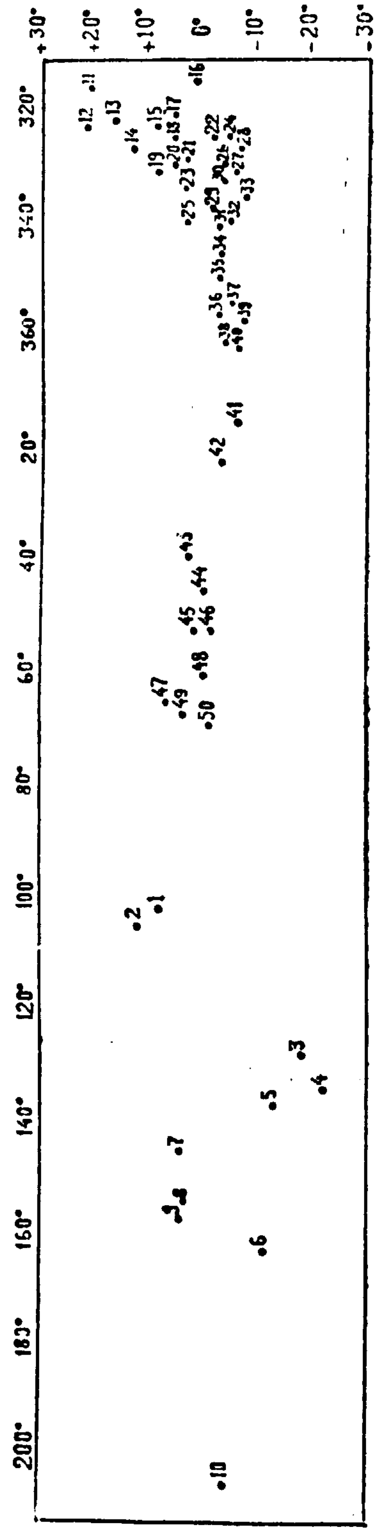

Figure 1

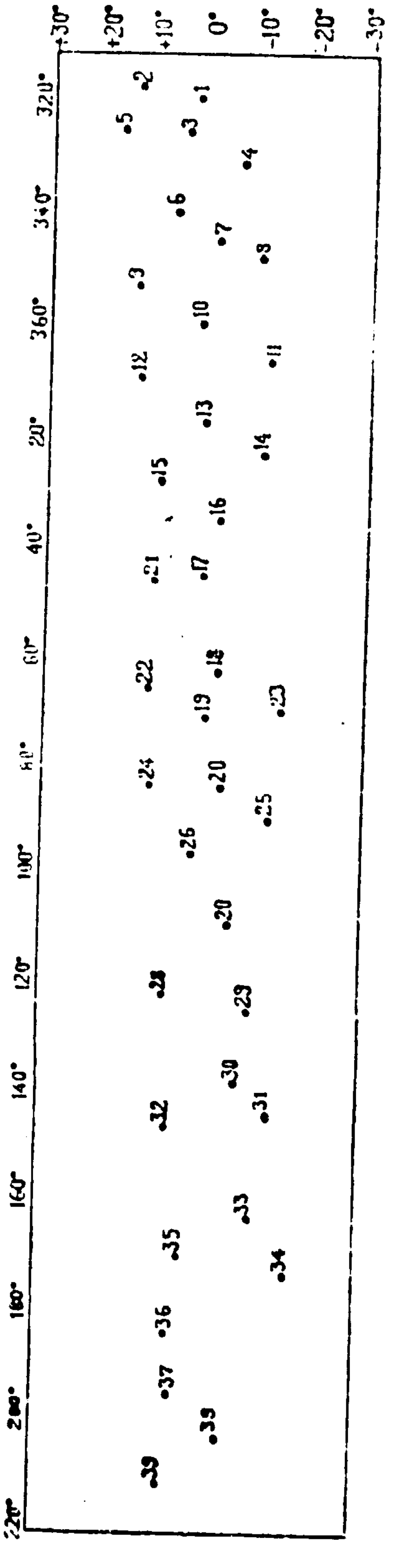

Figure 2

also explains the circumstance that Barnard's designations were not put into use. In addition, the statistical study of Barnard's catalog was not carried out.

In examining Barnard's catalog, we should take one more circumstance into consideration, which is of great significance. Compilation of the catalog was carried out in that epoch when it was impossible to consider interstellar absorption of light an established fact. Then, more or less comprehensive investigations of dark nebulae practically did not exist. Nothing was known about the total mass of interstellar matter, the average characteristics of dark clouds, etc.. Therefore, in light of contemporary data on dark nebulae, Barnard's catalog can not satisfy all requirements.

It follows from what has been said that we can not take Barnard's catalog as the basis for the compilation of a catalog of dark nebulae, although Barnard's maps retain their value for the study of the structural features of a number of dark nebulae.

§ 2. Material Utilized

Appearing in 1934-1936, Ross and Calvert's atlas of the Milky Way, a continuation and improvement of the work undertaken by Barnard on the photographing of sections of the Milky Way, makes the morphological study of the Milky Way possible. It surpasses Barnard's atlas in many respects, and is distinguished by the high quality of the photographic execution.

Ross and Calvert's atlas represents quite well the entire galactic region of the Milky Way between the galactic latitudes $b=\pm25°$, excluding the 85° zone from $\ell=220°$ to $\ell=305°$. This galactic region is covered by thirty-nine photographs of the Milky Way, each of which encompasses an area of the heavens of 21° x 21°. Various sections are taken at different exposures, which differ by an average of one hour, as a result of which different limits of penetration are achieved in the photographs. On the average, it is equal to 16.5 hours. The photographs in Ross's atlas have a scale of 1 mm=236° and dimensions of 320 x 360 mm, on the average.

The location of the centers of the photographs in Ross's atlas is shown in figure 2. As is evident, they are located uniformly and overlap each other in nearly all cases; this makes it possible, first, to record the majority of dark nebulae in several photographs and, second, to interrelate the photographs for listing in a single system during the evaluation of the darkening of dark patches. /47

Ross's atlas gives the equatorial coordinates of the center and four corners for each photograph, the galactic coordinates of the center of the photographs, the time and place of the photography, and the duration of the exposure.

We conducted recording of the dark nebulae in the photographs of Ross's atlas in the following manner. We made up maps for each photograph. This work is similar to that done by Barnard in the second part of his atlas. All "topographical" and measuring work was done on these maps. Outlines and centers of the dark patches were drawn on them, lines indicating the direction of their primary orientation drawn, numbers from Barnard's catalog and our number assigned, and some structural features of separate regions of the heavens noted. Only for photograph No. 14 was no map compiled, since not a single as yet unaccounted for dark nebula was detected in it. Thus, a total of 38 maps was compiled. The dark nebulae located, thanks to the mutual overlapping of the photographs in Ross's atlas, on two maps compiled independently of each other were compared with each other, which was a good verification of both the fact of the existence of dark nebulae, and of the values of their characteristics. Some dark nebulae were even recorded on three maps. There were cases when a dark nebula, which was easily detected on one photograph, was difficult to see in another. For example, a region rich in dark nebulae in the constellation Orion is represented in photographs Nos. 30 and 31. Two long, narrow, dark belts of about $\alpha=4^h40^m$, $\delta=25°$ are easily noted in photograph No. 30, but are almost absent in photograph No. 31. Similar cases are rarely encountered, but they require especially careful and thorough examination all the same. In such cases, we enlisted Barnard's atlas or other photographs available to us for supplementary examination.

Our maps are identical in scale to the photographs in Ross's atlas. They can have independent meaning for working purposes, since they depict the dark places of the Milky Way in a large portion of the galactic region. However, a coordinate grid and other celestial objects are not drawn on them, which makes their use difficult.

Some ambiguity is inevitable in establishing the outlines of dark nebulae, since nebulae with completely well-pronounced borders are rarely encountered. But, nevertheless, the outlines drawn on the map satisfactorily characterize the features of the shapes of the dark nebulae. Examples have been encountered when it is difficult to establish the border between a dark nebula and the background—the dark background changes so smoothly and imperceptibly into the light. In such cases, we did not draw the outlines. In those cases when the dark patches were distinguished quite clearly, we tried to outline them with all possible accuracy, in order to capture the finer structural features of the dark nebulae.

The outlines of the dark nebulae were drawn in the following manner. A transparent cellulose film was laid on a photograph in Ross's atlas, and the outlines of the dark patches were drawn on it with ink. Absorbing light, the film made the photograph of low contrast, but we tried to get around this by means of repeated and careful examination of the photograph alternately— with the film and without it. From the cellulose film, the outlines of the dark nebulae were copied onto graph paper. /48

The position of a dark nebula in the heavens is, of course, one of its characteristics; therefore, it is desirable to draw the centers of the dark patches with all possible accuracy. But, dealing with such elongated and, in many cases, formless objects as dark nebulae, one is perforce limited in accuracy during the drawing of the position of their centers, and no more is required of the coordinates of dark nebulae than what they can provide; in any case, they are fully sufficient for their recording and identification.

By the center of a dark patch, we mean its geometric center, the determination of which is very simple in the case of a regular geometric shape, but in the case of a formless patch, the centers were drawn more or less approximately. We tried to also take into account the fact that, in some cases, dark nebulae have different darkening in different places, and this should be kept in mind during determination of the center if we want this center to coincide with the projection of the "center of gravity" on the picture plane.

After we already had the maps, on which the outlines of the dark nebulae were drawn, we were able to draw one more characteristic on them. It is common knowledge that the dark nebulae lie in different directions in the picture plane. In the case of a regular ellipse, its long axis can indicate this direction or orientation, but in the case of a formless patch, especially when it is elongated or filamentous, this direction, which we conditionally called the "direction of orientation", can be drawn with great confidence in many cases. We drew these directions in all cases, when the shape of the dark nebulae permitted, refraining only in cases of round, triangular, square, and complex filamentous shapes.

In all cases, we tried to identify the dark nebulae we had recorded with Barnard's nebulae. In many cases, the nebulae coincided completely or partially, i.e. Barnard's nebula turned out to be part of ours. In both cases, we put the number from Barnard's catalog on the map. But, in the majority of cases, the dark nebulae recorded on our maps were not found on Barnard's, or the corresponding section of the Milky Way was not represented at all in the atlas. Many of Barnard's nebulae were absent in ours, since they were not detected in Ross's photographs because of the latter's small scale. There were cases when we divided one of the dark nebulae represented by Barnard into several parts, for some reason, but this was extremely rare.

In addition, all structural features observed by us or suspected in separate regions of the heavens were noted on the maps, as well as all structural features of the dark nebulae themselves. They will be covered in detail in the next chapter of the current study.

§ 3. Statistical Weights of Dark Nebulae

In the compilation of a catalog of dark nebulae, it is extremely important to correctly approach the selection of a principle upon which one can base the establishment of the existence of dark nebulae, i.e., in other words, to find criteria of the presence of dark nebulae, since an observable dark "patch" can be interpreted either as the fact of existence /49 of a dark nebula in the given place, or as the actual absence of stars. Consequently, the question can be posed thus: what kind of objective reasons do we have available for the resolution of the question—is there really a dark nebula at the given point in the heavens, or is it the actual thinning of the star field.

It should be noted that, irrespective of whether we have a dark nebula or a starless region in the direction of the dark patch, interest in compilation of the catalog is not weakened, since it would be fairly interesting, from the point of view of problems of structural astronomy, to study regions free from stars and discover some regularities or other in them.

During the discussion of the question on criteria for the presence of dark nebulae, we were guided by that simple notion that the ragged structure of the Milky Way is created basically because of the presence of light-absorbing dark nebulae in the environs of the sun, which are non-uniformly distributed in space.

Actually, it is already quite impossible to reconcile oneself to the assumption of the existence of "empty places" along the plane of the Galaxy, especially since extragalactic objects are not omitted here. It remains to attribute the raggedness of the Milky Way to the two following reasons: either it is caused by the non-uniform distribution of absorbing matter, or by natural fluctuations in star density. In all likelihood, both reasons act together. However, the influence of the former prevails. We omit physically connected groups (globular clusters, etc.), which are easily discerned, from the examination.

The studies of V. A. Ambartsumyan [39], V. Ye. Markaryan [12], Kreiken, and others, confirmed the opinion in astronomy that the non-uniformity in the distribution of apparent stellar density in the Milky Way is caused chiefly by the ragged structure of the light-absorbing matter in the environs of the sun.

Actually, if N(m) is the average number of stars brighter than the apparent stellar magnitude of m per square degree, and N'(m) is its value for some region, then the magnitude:

$$\Delta N(m) = N'(m) - N(m) \qquad (1)$$

can serve as a standard of fluctuation in the number of stars. One can calculate the most likely value of relative fluctuation, which depends only on the average stellar density, according to the formula well-known from statistical physics:

$$\delta = \sqrt{\frac{[\Delta N(\overline{m})]^2}{N(m)}} = \frac{1}{\sqrt{N(m)}} \qquad (2)$$

On the other hand, this same magnitude can be determined by tabulating stars. Thus, we can compare the natural fluctuation δ_{NAT} with the observed value of the fluctuation in stellar density δ_{OBS}. According to Markaryan's calculations, we have, on the average:

$$\frac{\delta_{NAT}}{\delta_{OBS}} = 0.1. \qquad (3)$$

Thus, in observable deviations in stellar density, 0.1 part is caused by natural fluctuations in the number of stars, and the remaining 0.9 can be attributed to dark nebulae. (The effect of errors in determination of extreme stellar magnitudes is imperceptible). We are not able to distinguish one decrease in stellar density, caused by the first or second reason, from another, but it is possible to establish that limit of the degree of thinning of stellar density beyond which one can confirm the existence of a dark nebula. The value of (3) can be such a limit. /50

The shape of the dark patch itself can play some role for the establishment of the presence of a dark nebula in a given place in the heavens. The filamentous structure, tendency toward general orientation, complex vortical and ragged shapes, and, in many cases, inclination towards grouping of dark nebulae, and others, point at the notion that, in dark "patches", we are dealing with a huge mass of light-absorbing matter, which is divided, torn, and condensed into separate formations under the influence of some forces or others.

A decrease in stellar density with an increase in galactic latitude, or for another reason of a regular nature, is easily distinguished by its scale and regularity of diminution. It usually switches smoothly and without perceptible borders into a scanty stellar background, and this change takes place on a wide front. Therefore, there is no danger in attributing a decrease in stellar density of such a type to dark nebulae.

It is necessary to note here that we sometimes had to divide some dark "patch" or another into several dark nebulae. This was done in those cases when the separate parts of the whole were distinguished from each other by blackness, or the very shape of the dark patch prompted it.

Dark nebulae differ among themselves both in dimensions and in blackness. The most diverse patches are encountered in the heavens: small globules and vast black zones of several dozen square degrees; very dark patches in which stars are almost absent, and hardly perceptible grayish filaments. It is quite evident that all of these objects do not always play an identical role in statistical computations. The study of the spatial distribution of a mass of dust matter, which, it seems to us, should give some idea of the nature of the connection between the stellar and dust components of our Galaxy, depends a great deal on the mass, i.e. on the dimensions and density of individual dark dark nebulae. Therefore, it is wise to attribute a weight to individual dark nebulae, which is proportional to their mass.

We will designate the mass of a dark nebula with the letter M and represent it as the product of the volume V times the density of the matter ρ in the dark cloud:

$$M = V\rho \tag{4}$$

or

$$M = \frac{4}{3}\pi R^3 \rho, \tag{5}$$

where R is the radius of a sphere having a volume V. It is apparent that (5) can be rewritten as

$$M = \frac{4}{3}\pi R \rho r^2 \sin^2 \omega, \tag{6}$$

where r is the distance to the dark nebula, and ω is the angle at which the radius of the nebula is visible.

The projection of the dark nebula onto a picture plane gives an apparent surface area σ. The dependence between σ and V, in view of the irregular shapes of individual dark nebulae, is impossible to establish, but when we have many dark nebulae, which have different shapes and are oriented randomly in space, then it is possible to assume that the average radius of a circle, having a true area $\bar{\Sigma}$, is proportional to the radius of a sphere, the volume of which is V, i.e. one can write down the equation:

$$\sqrt[3]{\bar{V}} \sim \sqrt{\bar{\Sigma}} \,. \tag{7}$$

With the predominance of elongated nebulae, this last assumption is, of course, somewhat bold, but we make it, bearing in mind that the computed magnitudes are determined only with slight approximation. /51

Thus, assuming proportionality between the radii indicated above, we would make an error for each individual nebula, but these errors are mutually compensating, to some extent, and the error for some direction, where many dark nebulae are encountered, becomes insignificant. After what has been said, and according to (5) and (6), one can write down the equation:

$$\sigma = \pi \sin^2 \omega . \tag{8}$$

On the other hand, the product ρR, as is common knowledge, is proportional to the light absorption of stars passing through a dark cloud, expressed in stellar magnitudes ε, since it is assumed that matter is distributed roughly uniformly in a dust cloud.

Thus, taking into consideration equation (8) and

$$\varepsilon = c' R \rho , \tag{9}$$

one can rewrite (6) as

$$M = k r^2 \sigma \varepsilon , \tag{10}$$

where

$$k = \frac{4}{3c'} . \tag{11}$$

It is not hard to see that the magnitude of ε can be replaced by the magnitude of $\Delta N(m)$, which is proportional to it. Actually, we will expand the function $N(m-\varepsilon)$ and confine ourselves to the first two terms:

$$N(m-\varepsilon) = N(m) - \varepsilon A(m) \tag{12}$$

Under the conditions which occur in our case, the equation:

$$N(m-\varepsilon) = N'(m) \tag{13}$$

is maintained, and we obtain:

$$\varepsilon \sim N(m) - N'(m) = \Delta N(m) \tag{14}$$

since the magnitude of A(m) is roughly equal for all of the photographs.

Equation (10) is rewritten thus:

$$M = k\sigma\Delta N(m)r^2. \tag{15}$$

We will introduce the designation:

$$p = \sigma\Delta N(m), \tag{16}$$

and call the magnitude p the "statistical weight"; we obtain:

$$M = kpr^2. \tag{17}$$

The magnitude of p can be determined by our measurements. It would be proportional to M if all dark nebulae were located at equal distances. However, one can pose the question thus: if we have a set of dark nebulae—what kind of dependence is there between the average values of mass and the statistical weight for this group? We will rewrite equation (17) thus:

$$p = M\frac{1}{r^2}. \tag{18}$$

It is evident that the mass of the dark nebula M and the inverse magnitude of the square of the distance $1/r^2$ are random magnitudes which are independent of each other and, therefore, the theorem that the average value of the product is equal to the product of their average values can be used for them, i.e. /52

$$\overline{p} = \overline{M}\,\overline{\frac{1}{r^2}}. \tag{19}$$

Our dark nebulae are basically located in the plane of the Galaxy, and nebulae located no farther than 700 parsecs (see chapter IV) are accessible for us. One can assume that, in this comparatively small volume of space, the function of the plane does not depend on the galactic longitude ℓ. In such a case, we find that the magnitude $\overline{1/r^2}$ has the same value for all longitudes ℓ.

The assertion that $\overline{1/r^2}$ does not depend on ℓ can be verified in the following manner. From physical considerations, we can assume that the average mass of the nebulae $\overline{M}$ is not a function of the coordinates. In such a case, the distribution $\overline{p}$ according to galactic longitudes ℓ can characterize the distribution of the magnitude of $\overline{1/r^2}$ according to ℓ. This distribution is presented in figure 3, which is compiled according to the data in table III (see chapter IV). It is evident from this figure that $\overline{p}$ is about the same for all directions, and one can say that this denotes that $\overline{1/r^2}$=const.

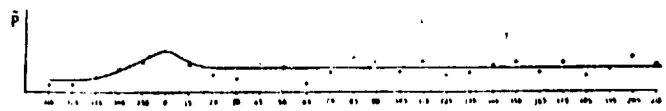

Figure 3

As an exception, $\overline{p}$ has a maximum in the direction $\ell=5°$, and it turned out, according to our curve, that dark clouds are located very close to us in this direction.

Thus, with posing of the question roughly statistically, one can take $1/r^2$ as constant, and then formula (19) will take the form

$$\overline{M} = k\overline{p}, \tag{20}$$

i.e. the magnitude of $\overline{p}$ can be utilized in some computations as the statistical weight.

Only $\overline{p}$ will figure in subsequent computations, and in cases where we will assert that the magnitude of p is proportional to the mass M, we will bear in mind the proportionality of the average magnitudes. This also dictates the designation "statistical weight" that we introduced.

§ 4. Determination of the Values of the Characteristics of Dark Nebulae /53

The photographs in Ross's atlas are not suitable for the determination of the equatorial coordinates of dark nebulae by the method of photographic astronomy, since it is impossible to carry out measurements on them. But, we do not require especially high accuracy here, since the centers and outlines themselves are not completely definite, and this makes attempts at deriving their exact positions superfluous. We will not set ourselves the purpose here of solving any kinematic problems with respect to dark nebulae. Therefore, we selected a rougher, but easy method of determining the equatorial coordinates of the centers of dark nebulae.

The method consists of the following. The photographs in Ross's atlas are identified with Franklin-Adams' maps, on which the centers of the dark nebulae have been drawn, and then, coordinates are set off using a superimposed coordinate grid. Such measurements make possible the determination of the positions of dark nebulae with accuracy up to 15 minutes of arc, which is fully acceptable for such elongated objects as dark nebulae. The switch from equatorial coordinates to galactic was carried out using the well-known Olson tables.

After we obtained the outlines of the dark nebulae on the maps, we could determine the areas encompassed by the outlines. Each area σ is a projection of the given dark nebula on a picture plane. Its magnitude depends on the actual dimensions of the dark nebula and the distance to it. It can not directly furnish information about the actual dimensions of the dark nebula or about their distribution in space, but by comparing it with other characteristics of dark nebulae, one can obtain some data relative to the geometric properties of dark clouds. Determination of the apparent surface area σ was carried out using Amsler's planimeter. Here, determinations of σ were carried out several times for each cloud and the average value taken, which provided accuracy with a standard deviation of 2 planimeter units, or 0.06 square degrees. Using a conversion factor suitable for the planimeter's abstract units, the apparent surface area σ was expressed in square degrees.

We could not determine σ for small globules, as well as for individual black filaments, since the accuracy of the planimeter did not permit it. Thus, values of σ for those dark nebulae, the σ of which is less than 0.1 square degrees, did not go into the catalog.

Since one can find the direction along which the nebula is oriented for the majority of dark nebulae, it becomes interesting to elucidate the question of the general orientation of dark clouds in the heavens relative to the galactic equator.

We have the opportunity of determining the least apparent angle φ contained between the galactic equator and the direction of orientation in the picture plane. The determination of the angle φ was carried out in the following manner. Having the direction of orientation for a dark nebula on the maps, we measured the angle between it and the direction of the axis of the graph squares on the maps. The latter always coincided with the right edge of the photograph in Ross's atlas. Then, by determining the angle between the edge of the photograph and the galactic equator—and this is possible, since the coordinates of the corners of the photographs are given in Ross's atlas,—we determined the angles φ.

The "blackness" of a dark nebula in the photograph depends on the density of the matter in the dust cloud and the distance to us. /54

The darkening of dark nebulae could be conditionally expressed by the difference

$$\Delta N(m) = N(m) - N'(m)$$

and determined by means of tabulating stars; however, we rejected this means, since it required the carrying out of tabulations of all stars in the entire region of the Galaxy under investigation. This is excessively tedious work. It was also impossible to determine the darkening by photometric means, since it is awkward and almost impossible to conduct normal photometric measurements on the photographs in Ross's atlas.

The method we chose consists of the following. The interval from the brightest places in the Milky Way (star clouds, bright diffuse nebulae) to the darkest patches, in which stars are almost absent, was divided into five stages. The lightest places were assigned a "zero" darkness, and the "blackest" dark nebulae—a "five" darkness. The darknesses which are included in the zero to one range we attributed to fluctuations in the stellar surface density, and the corresponding dark patches were not entered into the catalog.

The evaluation of the stages of darkening of the dark nebulae was conducted visually. Such an evaluation of $\Delta N(m)$ gives accuracy which is satisfactory for our purposes, since the weights p computed according to it have only statistical meaning.

It was interesting to compare the $\Delta N(m)$ we determined wi the star tabulations known from the literature, and thus check how our visual evaluations depicted reality. The known, quite extensive studies of the regions of the Milky Way, in which star tabulations are carried out, can serve as appropriate material for such a comparison. It was even dark nebulae that were studied in similar investigations and in many cases, maps of the regions of the Milky Way are given with the apparent density of the stars.

However, one substantial difficulty is detected here. As a rule, star tabulations were conducted in all these studies up to the 15th stellar magnitude, inclusive, while the maps in Ross's atlas, which serve as our basic material, are saturated with a rich stellar background, including stars of the 17th magnitude. In this connection, it was difficult to compare our material with the star tabulations for two reasons.

First, the formula derived in the previous paragraph

$$\Delta N(m) = \varepsilon A(m)$$

indicates that the greater the A(m), the more rapidly $\Delta N(m)$ changes with a change in ε. This means that our material, which reaches the 17th magnitude, is more sensitive to any drop in stellar density, caused by dark nebulae, than the tabulation of stars up to the 15th magnitude.

Second, the $\Delta N(m)$ of dark nebulae located at the limit of penetration of stellar tabulations will be distorted, as a result of the absence there of a background of stars located beyond the nebulae, and nebulae which are even more distant than the stars of the 15th magnitude will not be detected at all. Meanwhile, our material makes it possible to determine the $\Delta N(m)$ of nebulae located up to the borders of stars of the 17th magnitude, and, therefore, we should not expect correspondence of the $\Delta N(m)$ of nebulae located beyond the limits encompassed by star tabulations. /55

However, the stellar tabulations possess that indisputable advantage that they are objective and more accurate than our determinations, and therefore, it is nevertheless advisable to carry out such a comparison.

The region in the constellations Orion and Gemini was investigated by V. V. Lavdovskii [35], and we decided on this study because a rather large region is covered in it, and the study itself is most characteristic in the sense of applicable methods in such cases.

The map compiled by V. V. Lavdovski is redrawn in figure 4. The isophots of the apparent stellar density are drawn on it. We extracted all dark nebulae, located in the region depicted by the map, from our catalog. This turned out to be 35 nebulae. Drawing them on the map, (they are designated with circles on the map), we determined the stellar density for each nebula according to V. V. Lavdovskii's scale, and then, we compared them with our catalog values of $\Delta N(m)$. The results are assembled in table I, in which the catalog number of the nebula, the galactic coordinates ℓ and b, the stage of $\Delta N(m)$ from our catalog, and the stage of $\Delta N(m)$ according to Lavdovskii are given.

TABLE I

№	l	b	$\Delta N(m)_c$	$\Delta N(m)_{Lav.}$	№	l	b	$\Delta N(m)_c$	$\Delta N(m)_{Lav.}$
120	157°.5	— 8.°6	3	3	153	171.°7	—6.°4	4	2
121	159.6	— 9.9	4	3	154	164.1	—1.9	2	2
129	162.3	— 8.7	4	3	155	158.9	+1.1	4	3
132	159.8	— 6.9	3	3	157	163.5	— 0.7	3	2
133	163.9	— 9.0	1	2	158	160.6	+0.2	3	2
135	157.2	—10.4	4	3	159	165.3	—1.3	4	2
136	164.0	— 7.1	4	2	162	160.9	+1.3	3	2
137	164.7	— 8.7	4	2	163	169.7	—3.3	1	1
140	162.1	— 6.3	3	2	164	164.4	+0.2	1	1
142	168.1	— 8.9	4	3	166	166.6	+1.2	2	2
143	166.4	— 7.6	5	3	167	167.0	+2.7	4	3
144	164.7	— 6.4	4	3	168	165.1	+4.0	3	2
145	169.6	— 9.2	3	3	169	169.1	+1.8	5	3
146	171.2	— 9.8	3	3	170	165.0	+4.4	2	1
147	172.3	—10.2	5	3	171	163.8	+5.2	3	2
150	170.0	— 7.4	4	3	173	171.9	+1.4	3	1
151	161.1	— 1.2	3	2	175	169.2	+4.0	3	2
152	171.3	— 6.7	4	3					

Lavdovskii's scale is three-stage, and its correspondence to our five-stage scale is depicted schematically in figure 5.

By carrying out comparison according to table I, one can draw the following conclusion. Of 35 cases, our determinations of $\Delta N(m)$ coincide with the value of $\Delta N(m)$, according to stellar tabulations, in 29 cases, i.e. 80%. Only 6 cases were encountered when there was a discrepancy. It should be noted that not a single nebula from our catalog showed up in light regions of the map, and conversely, all of the dark regions on the map were filled with our nebulae.

Consequently, we have basis to maintain that evaluations of $\Delta N(m)$ carried out by our method are reliable. /57

The fact that the apparent map of the Milky Way changes appreciably as a function of the different degrees of contrast of the photographs and the different penetration capabilities of the instrument should be emphasized. But, in this respect, Ross's atlas can be considered satisfactory, because of its homogenous implementation. Granted, considerations of an opposite nature were expressed [56], but the difference in the photographs in Ross's atlas is not a serious obstacle for our purposes, i.e. for the recording and drawing of the outlines of dark nebulae with an accuracy with which we are satisfied.

During the evaluations of the blackenings of dark nebulae, we tried to combine all of the photographs into a single system,

/56

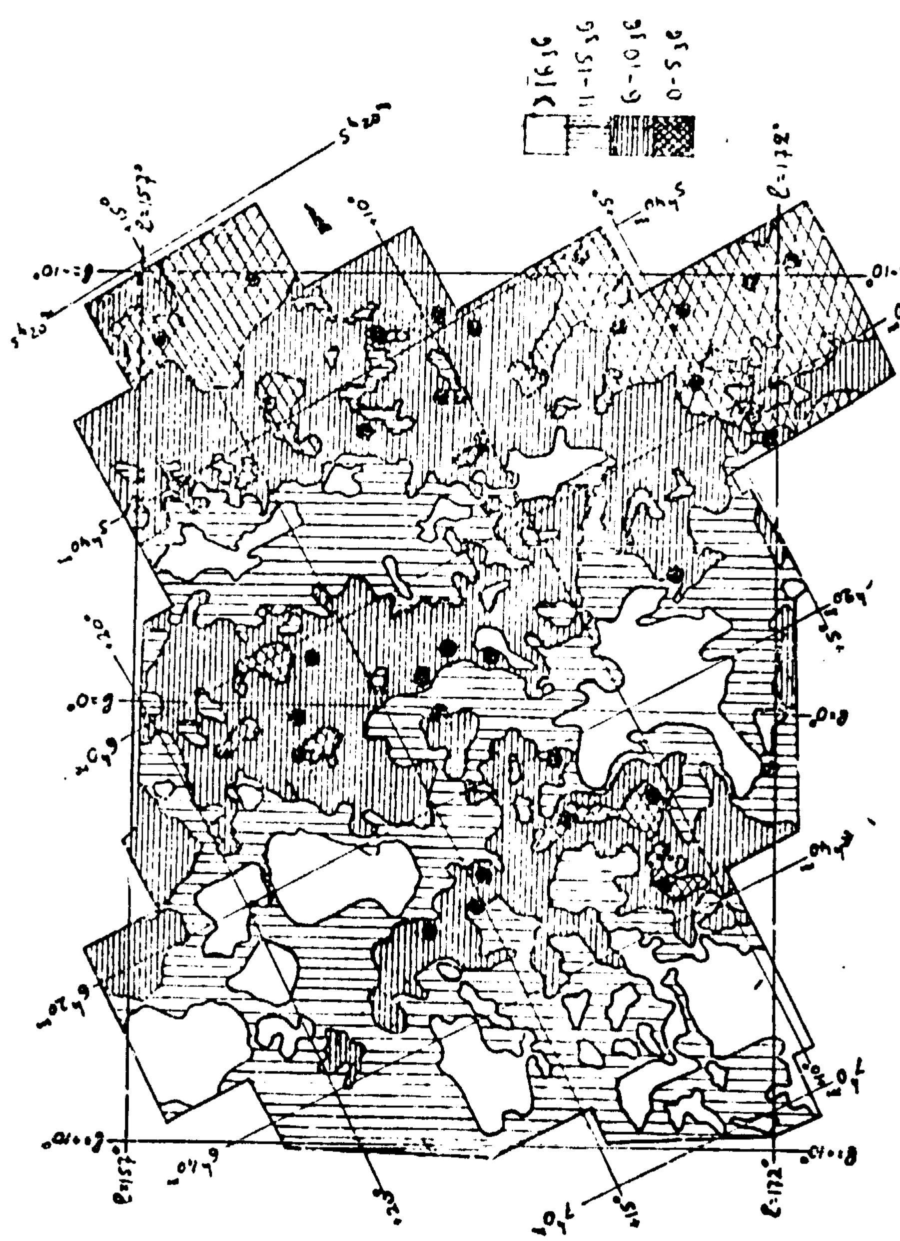

Figure 4

Key: a. Stellar magnitudes

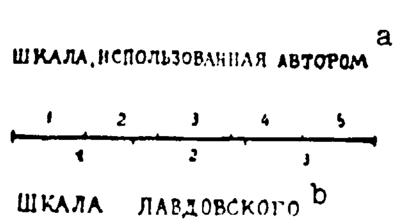

Figure 5

Key: a. Scale utilized by author b. Lavdovskii's scale using those dark nebulae which are recorded in two adjacent photographs. Thus, the blackenings of dark patches that we evaluated are free from the influence of the difference between separate photographs in Ross's atlas.

§ 5. List of Dark Nebulae

Our list, or tentative catalog, of dark nebulae contains 797 objects. The values of the following characteristics are given in it.

The series numbers are given in the first column. The dark nebulae are numbered in order of increase of direct ascension. Given in the second and third columns are the direct ascensions of α with accuracy of less than one minute of time, and the variation δ with accuracy of less than one-tenth of a degree. Given in the fourth and fifth columns are the galactic longitude ℓ and latitude b, with accuracy of less than one-tenth of a degree. 1900 years is the equinox period for both the equatorial and galactic coordinates. The values of the apparent surface area σ is given in the sixth column in square degrees, with accuracy of five-hundredths of a square degree. Given in the seventh column are the values of the position angles φ with accuracy of less than one degree. The weights p, calculated according to formula (16), are given in the eighth column.

The numbers from Barnard's catalog, and some data taken from other literary sources, are indicated in the notes column. Features of the structure and shape of the dark nebulae are also noted here.

We think that the current tentative catalog can not be free of both errors of an inadvertent nature and errors stemming from the imperfection, in many aspects, of the method utilized. In spite of its relative simplicity, the method we utilized can-not be free from deficiencies which are inherent in first en-deavors of a similar type.

And the present study is precisely a first endeavor and, so far as we know, there is no precedent for the given plan. It is also quite natural that our list still does not exhaust all dark nebulae located in the zone under investigation.

It should also be expanded and made more accurate with time and with the expansion of knowledge about individual dark nebulae, approaching a complete and thorough form. In the first place, it is necessary to supplement it with nebulae located in the zone from $\ell=220°$ to $\ell=305°$, and we intend to do this. However, we believe that, in the present "tentative" form, the catalog can not help but have significance for some problems of galactic astronomy.

The tentative catalog of dark nebulae we compiled is given below.

TENTATIVE CATALOG OF DARK NEBULAE

/58

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	q	p	a Примечания შენიშვნები
1	0 05m	+61°.4	85°.8	0.3	1.71		5	
2	07	+70.7	87.3	+8.8	4.42	57	13	
3	10	+63.0	86.0	+1.8				
4	16	+65.0	87.5	+3.1			59	
5	20	+60.0	88.6	1.4	3.90		12	
6	32	+69.1	89.3	+7.1	2.90	2	12	
7	32	+65.3	89.2	+3.3	2.04	11	8	
8	33	+58.3	89.3	4.0			0.25	Волокно b
9	33	+59.1	89.1	3.0	5.82	45	12	
10	35	+54.9	89.2	7.4	0.79		2	
11	39	+61.6	89.0	0.4	2.10	73	9	
12	40	+52.0	90.0	10.0	0.21		1	
13	45	+61.9	90.5	0.0	8.05		24	
14	49	+61.3	91.1	0.7	2.13		9	
15	53	+72.3	90.9	+10.3	3.41	19	11	
16	1 00	+60.7	92.4	1.2	1.34	70	4	
17	02	+58.3	92.8	3.6	1.40	87	4	
18	02	+58.7	92.0	3.2				
19	05	+70.2	91.5	+14.3	5.42	31	16	
20	09	+69.8	92.6	+7.9	0.79	20	2	
21	09	+66.3	93.1	+4.5	7.16		20	
22	11	+63.0	93.5	+1.2	6.00	16	24	
23	13	+59.2	94.2	2.6	1.34	40	3	
24	14	+57.9	94.5	3.6	1.10		1	
25	14	+60.7	94.1	1.0	1.16	68	5	
26	17	+51.3	96.0	10.3	9.05		30	
27	21	+54.3	96.1	7.2	2.35	51	7	
28	28	+56.6	96.5	4.8	2.47		7	
29	39	+58.5	97.7	2.6	6.40	9	10	
30	44	+65.9	96.5	+ 4.7	6.58	23	[illegible]	
31	47	+62.1	97.8	+1.1	3.54	2	14	
32	55	+60.2	99.1	0.4	4.30	0	17	
33	55	+70.8	94.4	+15.4	12.68		10	
34	2 03	+50.2	101.4	4.0	0.01	37	1	Волокно b
35	16	+60.6	101.6	+0.7	0.04	6	21	
36	27	+58.8	103.5	0.8	2.32		9	
37	31	+62.2	102.6	+2.9	0.37		1	
38	34	+61.0	103.4	+2.0	0.24		0.73	
39	3 21	+32.8	124.0	18.2	23.13	51	46	
40	37	+54.4	114.0	+0.8	8.02		32	
41	39	+31.9	128.6	16.5	8.00		26	
42	49	+49.1	118.7	2.1	0.92		21	
43	55	+39.5	125.0	8.7	30.48	17	152	
44	4 00	+54.7	116.3	+3.2	4.21		13	
45	02	+30.5	133.1	14.3	2.06	13	12	
46	03	+24.6	137.8	18.3	0.70	55	1	
47	03	+25.8	136.9	17.4	0.76	12	2	
48	06	+28.2	135.1	15.9	4.83	26	24	
49	09	+53.7	117.9	+3.4	1.58		0	
50	10	+42.1	126.1	4.9	4.30	79	17	
51	10	+54.9	117.0	+4.3	0.88	32	4	
52	11	+37.7	141.5	21.5			15	
53	12	+37.8	129.5	7.6	7.86	21	31	Волокно b
54	12	+25.0	139.0	16.4	0.70	47	5	
55	14	+26.9	137.9	14.9	1.10	21	6	
56	17	+45.3	123.8	1.7	1.43	82	6	
57	21	+47.7	123.5	+0.5	3.38		10	
58	21	+30.7	136.1	11.1	1.07	26	11	
59	22	+54.1	119.1	+5.0	0.61	54	3	
60	24	+51.1	121.4	+3.2	1.52		3	
61	24	+35.5	133.0	−7.5	10.79	20	43	
62	24	+46.3	125.0	0.1	0.21	35	1	

Key: a. Notes   b. Filament

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	q	P	a Примечания შენიშვნები
63	4^h24^m	+18°.2	146°.3	18°.8	0.01	14	5	
64	24	+23.1	142.3	15.6	2.38	26	10	
65	25	+28.7	138.0	12.0	4.97	2	12	
66	25	+24.1	141.8	14.8	0.76	30	9	
67	25	+53.1	120.0	+ 1.7	0.82	88	2	
68	26	+29.3	137.9	11.3	3.02	77	15	B 210
69	26	+24.7	141.4	14.3			0.25	Глобула b
70	26	+26.4	140.1	13.2	2.01	16	10	
71	26	+31.7	135.9	9.7	6.70	4	27	
72	27	+55.1	118.7	+ 6.2	0.40	39	1	b
73	30	+24.6	142.1	13.7			0.25	Глобула
74	31	+22.8	143.7	14.6	1.71		9	
75	32	+45.3	126.0	+ 0.3	4.97	19	15	
76	33	+48.8	124.1	+ 2.7	0.58	19	2	
77	33	+38.5	131.9	4.1	6.19	18	25	
78	33	+15.4	150.0	18.9			20	
79	34	+25.0	141.9	12.3	2.22	3	11	
80	35	+32.3	136.8	7.8	2.83	21	9	
81	36	+43.9	128.2	0.2	2.50	27	5	
82	38	+22.5	145.0	14.2	0.40	18	1	
83	39	+54.1	120.7	+ 6.9	0.07	50	1	
84	40	+52.9	121.5	+ 6.2	0.03		0.15	
85	40	+25.0	143.3	11.6	3.29		3	
86	42	+30.4	139.3	8.5	3.32	20	13	
87	43	+32.4	137.9	5.9	1.04	28	4	
88	44	+22.7	145.0	12.4			15	
89	45	+51.8	123.1	+ 0.1	1.46	24	4	
90	45	+45.7	127.7	+ 2.2	0.12		0.01	
91	45	+44.8	128.5	+ 1.7	4.05	27	8	
92	45	+37.6	134.0	2.8	3.84	15	12	
93	46	+27.1	141.8	8.0	2.06	50	9	
94	48	+31.2	139.4	0.4	0.27	62	1	
95	49	+32.2	138.8	5.6	3.11		6	
96	49	+35.1	136.5	3.8	1.38		5	
97	49	+53.7	121.9	+ 7.7	0.55	31	0.55	
98	54	+25.7	141.0	8.8	5.12	12	16	
99	55	+44.5	129.8	+ 3.0	4.30	3	13	
100	55	+35.0	130.9	2.5	0.37		1	
101	55	+33.0	138.5	3.8	2.10	17	4	
102	56	+28.[illegible]	142.0	0.8	1.13	30	2	
103	57	+32.5	139.6	4.1	0.05		0.20	
104	5 00	+38.0	135.6	0.3	3.41	25	10	
105	02	+31.2	141.2	4.1	0.04		2	
106	04	+33.9	139.2	2.1	3.54	51	7	
107	05	+19.6	151.2	10.2			17	
108	06	+10.8	158.9	14.9	0.58		3	
109	12	+23.7	148.7	6.6	2.01		6	
110	12	+20.3	140.6	5.0	3.08		15	
111	15	+22.1	150.4	7.0	3.47		10	
112	15	+ 7.9	162.6	14.7	6.55	10	26	
113	18	+31.6	142.9	1.0	3.66	35	7	
114	20	+36.4	139.2	+ 2.0	1.68	28	5	
115	20	+38.0	137.9	+ 2.9	3.87	25	12	
116	21	+57.0	121.8	+13.3	1.40	57	7	
117	21	+62.1	117.2	+15.9	3.41	27	10	
118	22	+10.0	161.6	12.1	0.79	30	0.79	
119	23	+25.0	140.7	14.6	12.31	11	40	
120	25	+15.3	157.5	8.6	6.04	42	18	
121	25	+12.8	159.6	9.0	3.90	80	16	
122	26	+31.4	144.0	0.6	5.82	15	12	
123	26	+28.9	138.2	11.5	1.43	40	7	
124	26	+ 9.7	162.4	11.4	0.70		0.70	
125	26	− 5.4	176.0	[illegible]	1.01	37	1	
126	29	+20.4	145.2	+ [illegible]	16.79	51	67	
127	31	+ 8.6	164.1	10.9	3.66		4	

Key: a. Notes b. Globule

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	q	p	a Примечания შენიშვნები
128	5^h33^m	+52°.1	127°.0	+12°.3	1.10	3[illegible]	5	
129	35	+11.2	162.3	−8.7	0.82	11	3	
130	35	8.0	170.0	−18.0	3.95	65.12	21	
131	36	+32.5	144.3	+2.7	0.15		0.70	B 34
132	36	+14.2	150.8	−6.9	3.30		11	
133	36	+9.9	163.5	0.0	2.05	31	3	
134	38	−5.4	177.5	−10.2	4.00	12	19	
135	39	+0.2	167.2	−10.4	1.37	6	6	
136	40	+10.0	164.0	−7.1	1.16	38	5	
137	40	+9.2	164.7	−8.7	0.12		0.39	
138	42	−1.2	174.1	−13.4	14.90	40	75	
139	42	4.0	170.7	−14.7	3.47	[illegible]	24	
140	43	+12.0	162.1	−0.3	3.57	12	11	
141	44	−7.2	180.0	−15.7	1.40	40	4	
142	46	+6.1	168.1	−8.9	0.85	84	3	
143	47	+8.3	166.4	−7.6	1.13	72 27	0	B 36 Волокно b
144	48	+10.3	164.7	−6.4	3.06	10	15	
145	48	+4.7	169.6	−9.2	3.11	83	9	
146	49	+3.0	171.2	−9.8	3.06	[illegible]	11	
147	50	+1.9	172.3	−10.2	0.03		0.15	
148	52	+0.7	173.7	−10.3	4.55	1	15	
149	54	−4.6	178.6	−12.3	4.07	79	15	
150	55	+5.3	170.0	−7.1	0.55	37	2	
151	59	+16.0	161.1	−1.2	8.75	20	26	
152	6 00	+4.4	171.3	−6.7	1.37	28	5	
153	02	+4.1	171.7	−6.4	1.10	21	5	
154	03	+13.1	164.1	−1.9	5.12	85	10	
155	03	+19.1	158.9	+1.1	1.71		7	
156	04	+2.7	173.4	−6.7	1.02	26	10	
157	06	+14.2	163.5	−0.7	3.14		9	
158	06	+17.5	160.6	+0.2	11.34		31	
159	07	+12.4	165.3	−1.3	0.21		0.05	
160	07	+3.3	173.2	−5.9	5.40	60	27	
161	08	−4.7	180.4	−0.2	9.24		37	
162	08	+17.4	160.9	+1.3	11.19	6	34	
163	09	+7.5	169.7	−3.3	2.30	40	3	
164	11	+13.0	164.4	+0.2	1.19		1	
165	12	+3.8	173.4	−4.4	5.04	47	17	
166	16	+12.4	166.0	+1.2	1.26	54	3	
167	25	+12.6	167.0	+2.7	2.07	48	8	
168	26	+15.0	165.1	+4.0	2.47	20	7	
169	26	+10.4	169.1	+1.8	2.30	86	12	
170	27	+15.3	165.0	+4.4	0.01		2	Волокно b
171	28	+16.8	163.8	+5.2	2.44	20	7	
172	29	+4.0	175.2	0.0	12.47	22	37	
173	30	+7.8	171.9	+1.4	0.18		0.55	
174	33	+7.6	172.5	+2.0	0.16		0.55	
175	34	+11.4	169.2	+4.0	1.43	19	4	
176	35	+7.9	172.[illegible]	+2.6	0.15		0.40	
177	36	+9.1	171.5	+3.4	1.04	10	4	
178	38	+8.3	172.4	+3.4	1.01	28	4	
179	38	+4.0	176.2	+1.4	2.57	49	6	
180	39	+9.5	171.5	+4.2	0.30	72	0.02	
181	45	−4.3	184.4	+1.0	3.02		6	
182	47	+4.6	176.8	+3.7	0.57	62	1	
183	51	−4.2	185.0	+0.5	0.37	67	1	
184	53	+2.4	179.5	+4.0	1.43	62	3	
185	54	−5.5	185.4	+0.5	1.10	62 1	5	
186	57	−4.7	186.1	+1.5	1.01	13	4	
187	58	0.0	182.1	+4.0	13.81	75	41	
188	59	−10.2	191.3	−0.6	4.15	24	16	
189	7 00	−3.5	185.4	+2.8	0.24		0.73	
190	05	−4.6	187.0	+3.3	0.04	13	2	
191	05	−6.4	188.6	+2.4	3.20	17	10	
192	07	−10.7	192.0	+0.8	0.14	8	46	

Key: a. Notes b. Filament

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	φ	p	a Примечания შენიშვნები
193	7^h08^m	−31°.2	210°.8	− 8°.7	0.27	33°	0.82	
194	08	−25.5	205.7	− 6.0	10.33	3	52	
195	08	−21.2	202.0	− 4.0	2.25	42	11	
196	08	−16.2	197.6	− 1.9	2.68	33	11	
197	09	− 4.5	187.3	+ 4.3	0.06		0.24	
198	10	−19.4	200.6	− 2.7	7.41		22	
199	15	−31.1	211.4	− 7.3	0.15		0.30	
200	16	−21.8	203.3	− 2.6	3.05	13	12	
201	16	−16.7	198.9	+ 0.1	2.47		10	
202	16	− 6.3	189.5	+ 4.9	1.62		2	
203	18	−14.0	196.8	+ 1.6	2.80	19	8	
204	20	− 0.9	185.5	+ 8.4	0.37	83	1	
205	22	−12.5	195.9	+ 3.2	3.54	34	11	
206	22	−16.3	199.2	+ 1.3	5.03	25	20	
207	24	−24.7	206.8	− 2.3	7.10	5	36	
208	24	− 6.3	190.8	+ 6.7	1.46		1	
209	25	− 8.3	192.7	+ 5.9	2.13		2	
210	26	−22.8	205.3	− 1.1	4.51	14	23	
211	28	− 3.8	189.0	+ 8.7	5.58	45	11	
212	28	−31.9	213.5	− 5.2	0.24		0.73	
213	29	−16.5	200.2	+ 2.7	1.28	9	4	
214	30	−14.1	198.3	+ 4.1	1.92	26	4	
215	34	−14.4	199.1	+ 4.7	1.40	34	4	
216	34	−29.8	212.3	− 3.1	3.08	40	6	
217	34	− 9.8	195.0	+ 7.0	7.22	46	7	
218	36	−26.1	209.4	− 0.8	0.49		2	
219	37	−27.7	210.8	− 1.4	1.04		3	
220	38	− 6.5	192.6	+ 9.6	0.67	72	1	
221	42	−22.2	206.7	+ 2.4	11.46	1	35	
222	42	−27.3	211.1	− 0.3	2.62		5	
223	43	−19.7	204.8	+ 4.5	0.40	40	2	
224	44	−29.2	213.0	− 0.9	1.52	4	5	
225	44	−26.7	210.8	+ 0.4	0.85	20	3	
226	47	−30.2	214.2	− 0.9	3.90	1	16	
227	48	−32.7	216.4	− 2.0	11.86		47	
228	8 00	−29.0	214.7	+ 2.1	1.86	50	2	
229	03	−24.7	211.5	+ 5.2	2.96	90	3	
230	05	−26.7	213.4	+ 4.7	10.27	75	21	
231	15 29	−35.9	304.3	+14.7	5.19		10	
232	32	−34.6	305.6	+15.3	0.79	12	2	
233	40	−34.3	307.1	+14.0	2.99	82	9	
234	47	−34.2	308.3	+13.7	0.91	39	2	
235	50	−37.8	306.3	+10.6	0.72	51	1	
236	16 10	−24.4	319.1	+17.2	0.15	48	0.15	
237	11	−37.5	300.6	+ 8.0	10.11		30	
238	12	−26.1	318.1	+15.7	0.83	48	0.83	
239	13	−35.1	311.7	+ 9.3	1.55	70	55	
240	14	−23.4	320.5	+17.2	2.88	24	6	
241	15	−37.4	310.2	+ 7.5	4.96	49	15	
242	16	−28.2	317.2	+13.7	0.34	75	0.34	
243	16	−32.5	314.0	+10.7	6.36		13	
244	18	−25.0	319.3	+15.5	0.91	89	2	
245	19	−34.4	313.0	+ 9.0	1.48		4	
246	20	−16.7	326.9	+20.5	1.52		6	
247	20	−20.7	323.6	+17.9	2.22		11	
248	22	−35.9	312.4	+ 7.5	2.08	70	6	
249	22	−24.3	321.1	+15.3	0.30	47	0.91	
250	24	−29.1	317.7	+11.7	0.23	89	0.23	
251	24	−33.3	314.6	+ 8.9	0.98		4	
252	24	−28.0	318.6	+12.4	0.26	8	0.27	
253	26	−36.4	312.5	+ 6.5	0.34	90	0.68	
254	26	−22.0	323.5	+16.1	0.57	9	1	

Key: a. Notes

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№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	q	P	a Примечания შენიშვნები
255	16^h27^m	−19°.3	325°.9	+17°.4	1.13	14	6	
256	27	−23.7	322.4	+14.8	0.57	19	2	
257	29	12.1	332.2	+21.6	2.35	76	7	
258	20	22.2	323.9	+15.4	0.57	20	1	
259	31	21.7	324.6	+15.4	0.23		0.45	
260	31	32.5	310.1	+ 8.4	2.54	30	5	
261	31	20.0	325.4	+10.0	0.34	21	0.66	
262	32	37.5	312.5	+ 4.9	0.05		3	
263	34	−20.0	320.4	+15.9	1.13	89	3	
264	34	−24.0	323.2	+13.4	5.04	33	15	B 44
265	35	−32.8	310.4	+ 7.6	0.23		0.91	
266	35	1.0	325.7	+15.0	0.42	1	0.83	
267	38	−27.3	321.2	+10.6	0.53		0.53	
268	38	−32.3	317.2	+ 7.4	1.74	20	5	
269	38	−36.2	314.2	+ 2.0	0.68	59	2	
270	38	−36.9	313.7	+ 4.4	0.87	10	3	
271	38	−35.1	315.0	+ 5.5	2.00	10	8	
272	39	−33.6	317.1	+ 7.0	0.19		0.76	
273	40	21.0	320.5	+14.1	1.89	13	6	B 45
274	40	30.1	319.2	+ 8.4	0.15	2	0.65	
275	41	38.1	313.1	+ 3.1	1.84	23	4	
276	41	33.1	317.0	+ 6.3	0.49	18	2	
277	42	−12.2	332.1	+19.0	2.07	14	6	
278	43	−13.8	332.9	+18.0	0.79	51	2	
279	43	−19.1	328.4	+14.7	1.31		4	
280	44	−17.7	329.8	+15.4	0.73		2	
281	44	−31.4	318.8	+ 7.0	1.00	77	8	
282	44	−23.5	325.0	+11.9	0.53	34	3	
283	45	−35.2	315.0	+ 4.7	1.21	83	5	
284	46	−15.2	332.1	+16.5	1.34	14	5	
285	47	−37.1	314.5	+ 2.8	0.57	70	1	
286	48	−32.9	318.1	+ 5.4	0.42	51	2	
287	49	16.4	331.7	+15.2	0.04	13	2	
288	49	33.0	317.8	+ 4.7	0.01	27	2	
289	50	23.1	320.2	+11.0	0.30	13	2	
290	50	−24.4	325.2	+10.3	0.83	20	0.8	
291	50	−21.9	327.2	+11.8	2.84		6	
292	51	−27.6	322.7	+ 8.1	1.21	4	1	
293	51	−22.5	326.8	+11.2	0.08		0.3	B 46
294	51	−36.7	315.5	+ 2.7	2.27	82	7	
295	52	−34.6	317.3	+ 3.6	0.42	87	2	
296	53	−14.2	334.0	+15.7	7.50	12	22	
297	53	−35.2	316.9	+ 3.1	0.72	81	3	B 240
298	54	−33.4	318.5	+ 4.1	0.64	40	3	
299	54	−32.1	319.5	+ 4.8	1.59		1	B 242
300	55	−23.0	327.0	+10.2	0.30	75	2	
301	56	−28.4	322.8	+ 7.8	0.61	1	0.01	
302	56	−36.2	316.5	+ 2.0	0.95	0	4	
303	56	−34.3	318.1	+ 3.2	0.23	73	1	B 50
304	57	−21.1	328.3	+10.5	0.08		0.2	
305	58	−35.6	317.2	+ 2.0	0.45		0.45	
306	59	−22.4	328.0	+10.2	0.26	20	1	
307	59	−22.0	328.4	+10.0	0.49	22	2	B 51
308	59	−33.4	319.2	+ 2.7	0.08	8	3	
309	59	+ 7.5	348.9	+ 4.2	0.79	90	2	
310	58	−25.9	325.0	+ 7.9	0.34	5	0.6	
311	58	−17.0	332.4	+13.1	5.79	19	12	
312	17 01	−35.9	317.4	+ 1.5	1.29		1	
313	02	−21.2	329.4	+ 9.9	0.38	49	1	
314	02	−25.4	326.0	+ 7.5	0.83	5	2	
315	02	− 7.2	341.4	+17.7	21.94	63	110	
316	03	−29.4	322.9	+ 5.2	0.26	31	0.81	B 243
317	03	−24.0	327.2	+ 8.1	2.23	23	4	
318	04	−22.4	328.7	+ 9.8	0.38	19	2	B 57,60
319	04	−11.6	337.9	+11.4	14.48		43	

Key: a. Notes

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	η	ρ	a Примечания შენიშვნები
320	17^h04^m	$-35°.2$	$318°.3$	$+1°.3$	1.63	51°	3	
321	05	−20.0	323.4	+ 4.8	0.15	32	0.15	
322	05	−20.8	330.3	+ 9.5	0.15	50	0.3	
323	05	−27.3	324.0	+ 5.7	0.70	32	4	B 59
324	06	−22.5	328.9	+ 8.5	0.11		0.6	B 246
325	06	−21.6	329.6	+ 8.8	0.30	19	0.3	
326	07	−19.3	331.7	+10.0	1.35		1	
327	07	−28.9	323.8	+ 4.5	0.08		0.16	B 248
328	07	−28.3	324.3	+ 4.8	0. 8		0.23	B 250
329	07	−33.7	319.9	+ 1.7	0.30		0.91	
330	08	−25.8	326.5	+ 6.1	0.38		0.8	
331	09	−22.4	329.4	+ 7.9	1.55	81	6	
332	09	36.7	317.6	0.4	0.54		1	
333	10	−27.2	325.5	+ 5.0	0.64	36	3	
334	10	−24.0	328.2	+ 6.8	1.21	22	2	
335	10	−20.8	330.8	+ 8.5	0.08		0.4	B 62
336	11	−21.3	330.6	+ 8.1	0.76	31	4	
337	12	−18.5	333.1	+ 9.5	0.49		2	B 64
338	12	−28.6	324.7	+ 3.7	0.11		0.23	
339	13	−25.0	327.8	+ 5.6	0.53	34	1	
340	14	−31.7	322.3	+ 1.7	0.53	7	2	
341	14	− 1.8	347.9	+18.0	17.58	63	71	
342	15	−30.1	323.8	+ 2.7	0.04	43	3	B 254
343	15	−27.0	326.4	+ 4.2	0.15	51	0.5	
344	15	−29.7	326.6	+ 4.4	0.08		0.4	B 65, 66, 67
345	15	−25.7	327.4	+ 4.9	0.23	16	0.4	
346	16	−28.6	325.2	+ 3.0	1.89	36	6	B 256
347	16	− 9.6	341.2	+13.5	10.27	37	51	
348	16	−34.6	320.3	− 0.4	0.08		4	B 258
349	16	−36.0	319.1	− 1.1	0.04	30	2	B 257
350	16	−22.0	330.6	+ 6.8	0.23	39	1	
351	17	− 6.7	343.9	+14.9	4.45	90	13	
352	18	−23.6	329.5	+ 5.4	.		1	B 72 Волокно глобулы b
353	19	−12.4	330.7	+ 6.0	0.10		1	B 262 Волокно c
354	19	−29.2	325.0	+ 2.2	0.57		2	
355	19	−19.0	333.6	+ 7.8	2.61	32	10	B 259
356	20	−23.0	330.3	+ 5.4	0.11		0.5	B 261
357	2[illegible]	−38.4	317.6	− 3.1	1.14	15	1	
358	20	−21.2	328.8	+ 6.4	0.61	16	3	
359	21	−31.9	323.0	+ 0.3	1.17	66	5	
360	21	−26.8	327.3	+ 3.1	0.72	61	4	
361	22	−24.0	329.7	+ 4.5		75	14.2	B 77
362	22	−14.1	338.2	+ 9.9	7.41	46	22	
363	23	−22.5	331.2	+ 5.1			15.7	B 269
364	24	−34.8	321.0	− 1.0	3.80		12	
365	26	−26.0	328.5	+ 2.7	5.68	17	28	
366	26	−18.4	334.9	+ 6.8	1.70	32	7	
367	26	−20.5	333.2	+ 5.7	2.58	38	13	B 268
368	26	−11.7	340.7	+10.3	8.78		26	
369	26	−15.5	337.4	+ 8.3	6.13	4	12	
370	28	−31.6	324.1	− 0.8	0.53	35	2	
371	28	+ 3.0	354.1	+17.3	15.88		32	
372	29	− 1.1	350.[illegible]	+15.1	0.79	44	0.79	
373	30	− 1.7	340.0	+14.6	0.67		1	
374	30	−22.9	331.7	+ 3.6	0.61	9	2	B 274
375	30	−16.0	336.7	+ 6.6	0.40	75	0.79	
376	31	−27.8	327.6	+ 0.7	0.95	15	4	
377	32	−25.7	329.5	+ 1.7			5	
378	32	−23.3	331.6	+ 3.0	0.38		2	B 272
379	33	− 5.5	347.1	+12.1	10.03		40	
380	33	−16.5	337.5	+ 6.4	0.43	71	0.13	
381	33	−19.8	334.7	+ 4.6	3.22	23	16	B 276
382	33	−24.1	331.0	+ 2.3	0.04		0.1	B 83
383	33	−30.6	325.5	− 1.2	0.95	27	4	
384	34	−28.9	327.1	− 0.3	1.17	5	4	

Key: a. Notes c. Filament
b. Filament, globules

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	q	p	a Примечания შენიშვნები
385	17h34m	−36°.6	320°.5	−4°.5	4.81	5	5	
386	35	−22.8	332.4	+2.6	0.30		1	B 277
387	36	−30.0	326.4	−1.4	1.48	27	6	
388	36	−27.0	326.5	+4.0	1.25	10	4	
389	36	−23.8	331.7	+1.9	0.30	5	0.6	
390	36	−17.3	337.2	+5.3	0.21	73	0.43	
391	37	−34.7	322.5	−4.0	0.05		4	
392	39	−10.0	343.1	+8.4	1.62	6	6	
393	39	−22.4	332.9	+0.4	1.44	7	7	B 279
394	39	−38.0	319.9	−6.0	0.38	3	1	
395	40	−16.4	338.6	+5.1	1.25	4	4	
396	41	−25.1	331.1	+0.3	3.29	71	10	
397	42	−19.1	330.3	+3.2	1.10	61	5	
398	42	−18.4	336.9	+3.5	2.01	53	6	
399	42	−14.0	340.3	+5.8	2.35	0	9	B 284
400	42	−6.1	347.6	+9.8	0.94		2	
401	42	+2.6	355.4	+14.0	18.01	36	36	
402	43	−4.4	349.3	+10.4	0.08	17	4	
403	44	−10.4	344.1	+7.2	1.86	13	7	
404	44	−3.2	350.4	+10.8	2.32	28	5	
405	44	−20.0	335.4	+2.0		36	[illegible]	
406	44	−37.4	320.9	−6.6	0.72	3	2	
407	44	−21.8	334.5	+1.0	1.70	22	8	
408	45	−29.2	328.0	−2.0	0.45		1	
409	46	−33.8	321.5	−7.6	1.21		6	
410	47	−16.8	339.0	+3.2	2.68	52	11	
411	48	−26.8	330.[illegible]	−0.9	4.35	27	17	
412	48	−32.2	325.8	−4.7	0.46		2	
413	48	−14.9	340.8	+4.1	3.75	17	11	
414	48	−13.0	341.9	+4.7	1.43	32	4	
415	48	−5.7	348.8	+8.7	1.80	12	5	
416	48	−7.2	347.4	+7.9	2.10	30	7	
417	48	−10.5	344.6	+6.4	2.07	0	8	
418	49	−28.2	329.3	−2.0	0.64	30	3	
419	49	−35.1	323.4	−6.3	0.76		3	
420	49	−36.2	322.4	−6.9	0.61	5	3	
421	50	−30.6	327.4	−4.3	1.52	30	5	
422	50	−20.0	328.8	−3.4	0.11	20	0.6	B 289
423	50	−18.7	337.7	+1.8	2.38		7	
424	51	−8.5	346.7	+6.7	2.53	40	10	
425	51	−4.0	350.6	+8.8	2.38	55	7	
426	51	−22.6	334.5	−0.4	1.04		3	
427	51	−27.7	330.1	−2.0	0.10	68	2	
428	51	−29.7	328.0	−3.9	0.19	9	0.8	
429	52	−31.9	326.5	−5.2	0.30	7	1	
430	52	−17.6	338.0	+1.9	0.09	38	0.46	B 84a
431	53	−21.6	335.6	−0.3	1.57	88	4	
432	53	−17.4	339.1	+1.8	0.21		0.85	
433	54	−15.1	341.2	+2.8	1.04		2	
434	54	−17.9	338.8	+1.4	0.06		0.18	
435	54	−20.6	356.3	0.0			4	
436	55	−33.3	325.6	−6.6	1.89		10	B 291 Волокнист. туманн. b
437	55	−29.4	329.1	−4.6	0.34	56	1	
438	55	−18.0	338.1	+1.1	[illegible]		0.27	
439	56	−19.0	338.2	+0.4	4.45	5	22	B 297
440	56	−34.0	325.1	−7.1	0.57		3	
441	56	−31.0	328.6	−5.1	0.64	38	2	
442	57	−13.4	343.1	+3.0	3.84		15	
443	57	+0.2	355.1	+0.6	3.00	51	4	
444	58	−4.8	350.8	+7.0	3.90	17	12	
445	59	−30.6	328.4	−5.9	3.05		9	B 295, 298
446	18 00	−28.6	330.3	−5.2	0.49		1	
447	00	−17.5	340.0	+0.2	3.50	33	14	
448	01	−29.4	329.6	−5.8	1.01	54	3	
449	01	−11.3	345.4	+3.2	4.57	35	14	

Key: a. Notes b. Filamentous nebula

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	q	p	a Примечания შენიშვნები
450	18ʰ02ᵐ	−27°.8	331°.2	− 5°.2	0.49		1	B 90
451	02	−16.5	341.0	+ 0.4	3.87	45°	15	
452	03	− 2.8	353.2	+ 6.8	8.02		32	
453	04	−24.3	334.4	− 3.9	9.49	7	47	
454	04	−28.4	330.8	− 5.8	0.18		0.73	
455	04	−26.9	332.2	5.1	0.61		2	
456	04	−20.4	337.8	1.6	4.36		13	
457	07	−13.1	344.6	+ 1.0	6.46	6	26	
458	07	−31.9	327.8	− 7.7	2.22	41	9	B 305
459	08	− 2.6	353.9	+ 5.8	7.07	2	35	
460	08	−18.6	339.9	− 1.9	0.30	13	0.91	B 304 b
461	10	−28.9	331.0	− 7.2	0.40		0.40	Волокно
462	10	−21.3	337.7	− 3.6	0.85		6	
463	11	−17.4	341.3	− 2.0	2.29		9	
464	11	−18.2	340.6	− 2.3	0.03		0.15	B 92
465	12	−22.4	337.0	− 4.6	1.08		4	
466	12	−31.5	329.0	− 8.8	0.12		0.24	
467	13	−23.6	336.1	− 5.3	0.27		0.54	
468	13	−26.5	333.5	− 6.7	0.24		0.49	
469	14	−24.5	335.4	− 5.9	0.30	71	0.61	
470	14	−27.4	332.7	− 7.3	0.58		1	
471	14	−32.1	328.6	− 9.5	0.18	58	0.55	
472	14	−31.3	329.3	− 9.1	0.06		0.06	
473	15	− 4.7	352.9	+ 3.3	4.42	17	18	
474	15	−20.7	338.9	− 4.3	3.29		16	
475	15	−28.4	332.1	− 8.0	0.91		2	
476	15	+ 0.9	357.9	+ 5.9	8.11		45	
477	15	−24.9	335.1	− 6.3	0.30	56	0.01	
478	16	− 7.9	350.2	+ 1.6	3.84	12	19	
479	16	−15.2	343.8	− 1.9	4.18		17	
480	16	−27.7	332.8	− 7.8	0.49	24	0.08	
481	17	−18.9	340.6	− 3.9	1.58		8	
482	17	−12.5	346.3	− 0.8	1.58	15	6	B 95
483	17	−25.7	334.6	− 7.1	1.34	2	4	
484	19	−16.6	343.0	− 3.3	1.74		7	
485	19	−24.0	336.4	− 6.7	1.34	80	5	
486	19	−13.5	345.7	− 1.7	1.62	13	6	
487	20	− 8.0	350.6	+ 0.6	7.47		30	
488	21	−30.4	330.8	−10.1	1.98		4	
489	21	−21.6	338.7	− 6.0	0.55	3	2	
490	21	−24.7	336.0	− 7.4			1	
491	22	−28.3	332.8	− 9.3	2.13	15	6	
492	22	− 3.8	354.5	+ 2.8	19.20	28	90	
493	23	−20.3	340.1	− 5.8				
494	23	−10.0	349.2	− 0.9	1.83		9	B 97 b
495	23	+14.9	11.3	+10.6		29	3	Волокно
496	23	−26.3	334.7	− 8.6	0.43	52	1	
497	23	−18.0	341.5	− 4.8	1.22	4	4	B 311
498	23	−25.6	335.4	− 7.2	0.34	10	1	
499	23	−13.7	346.0	− 2.7	0.88	8	3	
500	23	−22.9	337.0	− 7.0	0.58	78	2	
501	24	−24.3	336.6	− 7.5	1.52		5	
502	25	+12.9	9.7	+ 9.3	0.76	8	2	
503	25	−21.2	339.5	− 6.7	0.30		1	
504	25	−22.3	338.5	− 7.2	0.67	5	1	
505	26	−29.2	332.4	−10.5	0.37	7	0.74	
506	26	−26.2	335.1	− 9.1	0.24	0	1	
507	26	−15.7	344.5	− 4.3	1.49	83	4	B 312
508	27	−27.6	334.0	−10.0	0.85	0	3	
509	27	−18.7	342.0	− 5.9	1.43	9	4	
510	27	+ 0.9	359.3	+ 3.3	22.71	89	114	
511	27	−14.1	346.0	− 3.7	0.03		0.03	
512	27	− 8.2	351.2	− 1.0	0.73	20	2	
513	27	+12.4	9.6	+ 8.6	1.68	2	2	
514	28	+ 4.1	2.2	+ 4.5	7.38	48	30	

Key: a. Notes b. Filament

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	φ	p	a Примечания შენიშვნები
515	18^h29^m	−13°.4	340°.8	3°.9	0.24		0.24	
516	29	−19.7	341.3	6.8	1.58	26°	6	
517	29	10.6	340.4	2.5	2.90		14	B 314
518	29	14.4	345.9	− 4.3	0.94	4	0.94	
519	30	−23.5	338.0	8.7	0.52		1	
520	31	13.4	347.1	− 4.3	0.93		0.09	
521	31	8.8	351.2	− 2.2	0.61	20	2	
522	31	24.7	337.0	− 9.5	0.55		2	
523	31	10.0	350.1	− 2.7	1.43	39	6	
524	32	−25.9	336.0	−10.2	2.38		10	
525	32	−22.2	339.3	− 8.6	0.85	80	3	
526	32	−19.2	342.0	− 7.2	0.34		1	
527	32	12.3	348.2	− 4.0	1.08	52	7	
528	32	6.9	352.8	− 1.4	0.70	17	3	B 103
529	33	15.3	345.6	− 5.8	0.88	5	1	
530	33	−27.5	334.7	−11.5	0.85	14	3	
531	34	−17.2	344.0	− 6.7	2.86		6	
532	34	− 6.2	353.8	− 1.6	0.70	64	3	
533	34	−11.4	349.2	− 4.0	0.73	36	3	
534	35	−21.7	340.1	− 8.9	1.04		3	
535	35	−20.7	340.9	− 8.5	0.76		2	
536	36	24.1	338.0	−10.2	0.27		0.27	
537	37	24.7	337.6	−10.7	0.34	35	0.34	
538	38	18.2	343.6	− 8.0	0.64	5	1	
539	38	−10.6	350.4	4.5	0.37	7	1	
540	39	−19.7	342.4	− 8.9	0.12	48	0.25	
541	39	−12.2	349.1	− 5.5	2.32	54	9	
542	41	−21.4	341.0	−10.0	1.13	43	5	
543	41	[illegible]	346.8	− 7.2	1.43	34	4	
544	41	8.2	352.8	− 4.1	0.94		3	
545	41	7.2	353.7	− 3.6	1.22	8	1	
546	42	−13.4	348.3	− 6.6	1.28	45	5	
547	42	− 9.3	352.0	− 4.8	0.30		1	
548	42	−23.7	339.0	−11.3	6.55	47	33	
549	44	20.4	342.2	−10.3	1.83	[illegible]	5	
550	44	14.8	348.7	− 7.7	1.43	48	4	
551	45	4.9	356.2	− 3.3	4.14	30	21	b B 111 Группа глобул и темных туманностей: B 110, 106, 107, 113, 117a, 320, 322
552	45	3.0	357.9	− 2.5	3.84	26	10	
553	46	6.7	354.3	− 3.6	0.15	79	0.08	B 112
554	46	10.7	351.2	− 6.3	1.86	9	4	
555	46	− 7.2	354.3	− 4.5	0.46	9	0.01	
556	48	− 7.3	354.4	− 5.2	1.13	42	1	
557	49	− 1.3	359.9	− 2.5	0.24	34	0.08	
558	49	− 5.2	356.4	− 4.4	0.52		3	B 119a
559	50	+ 4.4	5.1	− 0.1	53.6	10	215	
560	50	8.3	353.8	− 6.1	0.55	40	0.55	
561	51	11.8	350.8	− 7.9	2.53	47	10	
562	51	18.9	344.4	−11.1	0.21	30	6	
563	51	−15.0	347.7	− 8.9	1.86		6	
564	51	9.0	352.8	− 6.8	0.27	10	0.55	
565	53	17.5	336.0	−10.7	4.02		12	
566	53	13.4	340.5	− 9.0	5.88		13	
567	53	0.7	0.0	− 3.1	0.21	25	0.04	
568	53	+17.8	17.3	+ 5.5	0.43	30	2	
569	54	7.3	355.1	− 5.5	0.88	14	2	
570	54	3.7	358.4	− 4.8	1.68	32	7	B 325, 4, 3
571	54	5.2	357.0	− 5.5		33	3	B 128, 132
572	54	+10.9	11.2	+ 2.0	2.56	32	12.80	
573	54	+12.2	19.7	−10.1	0.08	25	5	
574	55	+18.6	18.3	+ 5.4	1.05	13	8	
575	55	+15.6	15.5	+ 4.1	0.70	69	2	
576	55	16.0	346.9	−10.6	0.27	11	0.55	

Key: a. Notes

b. Group of globules and dark nebulae

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	q	p	a Примечания შენიშვნები
577	18^h56^m	−15°.3	348°.1	−10°.2	1.25	4°	2	
578	56	−9.7	353.3	−8.0	1.52	14	2	
579	56	−1.4	0.6	−4.2	0.3	60	1	
580	56	−0.4	1.5	−3.7	0.58	01	2	
581	58	+3.7	5.6	−2.2	0.27		1	
582	59	−8.2	354.9	−8.0	1.16	5	3	
583	59	−7.8	355.3	−8.0	0.94	8	0.94	
584	19 00	−6.5	356.6	−7.4	0.98		3	
585	00	+21.2	21.0	+5.6	0.30	3	0.92	
586	01	−12.3	351.4	−10.3	1.40	13	4	
587	02	−4.0	359.0	−6.7	0.98	03	4	B 135, 136
588	03	+18.4	18.9	+4.0	0.43	3	0.85	
589	03	+22.3	22.3	+5.5	0.40	2	1	
590	03	+20.0	20.3	+4.4	0.79		2	
591	04	−6.2	357.3	−8.2	1.25	25	4	
592	05	+16.7	17.6	+2.4	0.88		3	
593	06	+23.8	24.0	−5.4	0.15		0.30	
594	06	+17.8	18.7	+2.6	0.98	16	4	
595	07	+15.2	16.6	+1.4	1.22		4	
596	08	−4.9	358.9	−8.4				Глобула b
597	09	+17.4	18.7	+2.0	0.12	17	0.61	
598	10	+25.4	25.9	+5.6	0.18	2	0.55	
599	11	−1.0	2.8	−7.3	0.24	80	0.98	B 137
600	11	+20.5	21.6	+3.0	2.71		11	
601	11	+16.6	18.2	+1.1	0.64		3	
602	11	+15.0	17.0	+0.4	0.12		0.37	
603	12	+22.8	23.8	+3.2	0.27		0.55	
604	12	+11.6	16.6	0.0	0.15		0.40	
605	12	+10.9	13.4	−1.9	47.85		239	
606	13	−1.6	2.4	−7.8	0.03		0.15	B 139
607	13	+0.8	4.6	−6.9	1.25	22	5	B 138
608	14	+26.4	27.2	+5.3	0.23	31	1	
609	14	+7.5	10.6	−3.9	0.43	26	2	
610	14	+7.4	10.5	−4.0			2	B 330
611	15	−2.0	2.4	−8.7	1.16	10	5	
612	15	+1.7	5.7	−0.9	0.37		2	B 141
613	15	+5.0	8.0	−5.4	10.33	26	41	
614	15	+23.2	24.5	+3.5	0.18		0.55	
615	16	+20.7	22.4	+2.1	4.97		25	
616	18	+17.7	19.8	+0.2	6.25		31	
617	18	+27.4	28.5	+5.0	0.06		0.06	
618	21	+0.72	5.3	−8.3	2.44	25	10	
619	23	+23.9	25.9	+2.6	0.00		0.24	
620	25	+9.2	13.5	−5.4	2.08	6	11	
621	25	+23.5	25.8	+1.6	0.15	87	0.01	
622	25	+20.2	28.2	+3.0	1.28	20	3	
623	26	+23.9	26.7	+1.6	3.50	27	18	
624	26	+25.0	27.3	+2.2	0.52		0.52	
625	27	+21.4	24.3	+0.2	7.38	87	37	
626	27	+25.2	27.6	+2.1	0.46	50	1	
627	28	+29.4	31.3	+4.0	0.06		0.05	
628	28	+16.1	19.8	−2.7	8.93		45	
629	29	+12.0	16.4	−4.9				B 334 Волокно c
630	29	+21.3	27.0	+1.3	1.04		2	
631	31	+12.1	16.7	−5.3	0.05		0.24	B 337
632	31	+12.0	16.6	−5.4				B 336 Глобула b
633	31	+21.7	25.1	−0.5	12.25		61	
634	32	+30.4	32.6	+3.8	0.06		0.06	
635	32	+9.7	14.7	−6.7	2.22		9	
636	32	+7.3	12.6	−7.9			0.10	B 335
637	33	+25.3	28.3	+1.0	0.43	33	2	
638	33	+1.1	7.3	−11.2	14.45		43	
639	33	+4.5	10.3	−9.5	3.38	10	10	
640	34	+8.1	13.6	−7.9			3	

Key: a. Notes
b. Globule
c. Filament

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	q	p	a Примечания შენიშვნები
641	15^h35^m	$+17^\circ.3$	$21^\circ.7$	$-3^\circ.5$	0.40		1	
642	35	+26.5	29.6	+ 1.2	0.15		0.61	
643	35	+27.5	30.6	+ 1.7	0.79	19°	3	b
644	36	+10.2	15.7	— 7.3			1	B 141 Кольцеобразная
645	36	+10.8	16.21	— 7.0	0.70		4	B 143 Кольцеобразная совместно с N 644 c
646	37	+27.2	30.4	+ 1.2	2.06		10	
647	38	+ 7.2	13.3	— 9.2			0.15	B 338
648	38	+31.9	34.5	+ 3.4	0.12		0.12	
649	38	+29.4	32.4	+ 2.1	0.06		0.16	
650	39	+28.8	32.0	— 1.9	0.15		0.61	
651	39	+26.9	30.4	+ 0.0	0.54	18	3	
652	39	+18.8	23.5	— 3.6	0.82		2	
653	39	+ 8.3	14.4	— 8.9		11	7	B 339
654	39	+31.9	34.6	+ 3.2	0.09		0.09	
655	40	+17.5	22.5	— 4.4	0.30		0.30	
656	40	+32.2	35.1	+ 3.3	0.21	0	0.64	
657	41	+27.6	31.2	+ 0.7	0.09		0.36	
658	41	+32.2	35.2	+ 3.1	0.18	76	0.37	
659	42	+30.7	34.0	+ 2.1		20	0.12	
660	42	+ 6.9	13.6.	—10.15		46	2	
661	43	+31.7	34.9	+ 2.7	0.30	23	1	
662	44	+27.6	31.6	+ 0.1	0.46	23	0.91	
663	44	+30.2	33.8	+ 1.5	0.18		0.36	
664	46	+22.0	27.0	— 3.2	2.13	62	9	
665	46	+29.1	33.1	+ 0.6	0.88	39	4	
666	47	+30.2	34.1	+ 1.2	0.30	81	0.92	
667	50	+39.2	42.1	+ 5.0	0.43		0.43	
668	51	+30.7	35.1	+ 0.4	0.79		3	
669	52	+33.8	37.7	+ 2.0	0.91	8	4	
670	54	+31.8	36.2	+ 0.6	2.29	5	9	
671	55	+34.8	39.0	+ 2.1	2.44	3	10	B 144
672	56	+24.6	30.5	— 3.8		4	60	
673	57	— 2.4	7.1	—18.1	14.02		56	
674	58	+39.0	42.8	+ 3.8	2.04		1	
675	59	+37.5	41.7	+ 2.8	0.12		0.49	B 145 Треугольник d
676	20^h 01	+36.4	40.1	+ 1.8	0.76	4	2	B 146
677	04	+31.8	37.4	— 1.2	5.52	23	22	
678	04	+34.8	39.9	+ 0.5	0.30		0.92	
679	06	+35.4	40.6	+ 0.5	1.18		0.36	
680	06	+40.2	44.6	+ 3.2	0.55	68	1	B 343
681	08	+38.7	43.6	+ 2.0	4.72		9	
682	09	+42.6	46.9	+ 4.1	3.41	36	10	
683	11	+48.1	51.7	+ 7.0	1.10		0.12	
684	12	+44.6	48.9	+ 4.3	0.82	11	2	
685	16	+40.1	45.7	+ 1.6	2.35	9	7	
686	16	+36.8	43.0	— 0.3	13.91	29	56	
687	23	+39.7	46.1	+ 0.3	0.49	31	2	
688	24	+45.8	51.1	+ 3.9	0.18	25	0.55	
689	32	+65.1	67.4	+14.6	0.09	11	0.36	
690	32	+63.2	65.8	+13.4	0.24	10	0.98	
691	33	+39.0	46.7	— 1.7	18.50		25	
692	34	+31.7	41.2	— 6.4	16.97	42	44	
693	35	+56.7	60.8	+ 9.1	2.22	38	9	
694	35	+42.8	50.0	+ 0.5	11.92		60	
695	42	+67.3	69.9	+15.0	0.30	8	2	
696	42	+48.2	54.9	+ 3.0	0.76		0.76	
697	44	+38.3	47.6	— 3.8	2.38	23	10	e
698	47	+59.7	64.2	+ 9.9	0.21	7	1	Волокно
699	50	+55.1	61.0	+ 6.6	2.26	74	9	
700	52	+43.5	52.5	— 1.4	3.50	72	18	
701	52	+41.2	50.8	— 3.1	4.72		23	
702	54	+45.7	54.4	— 0.2	0.12		0.61	B 352
703	56	+46.5	55.2	0.0	0.27		1	
704	56	+57.7	63.5	+ 7.6	0.67		3	

Key: a. Notes
b. Ring-shapes
c. Ring-shaped with No. 644
d. Triangle
e. Filament

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	σ	φ	p	a Примечания შენიშვნები
705	20^h57^m	+47°.7	56°.2	+ 0°.7	2.62	39°	10	
706	57	+55.0	61.5	+ 5.7	0.30		2	
707	57	+77.1	72.9	+10.3	1.43		4	
708	59	+45.0	54.9	− 1.0	0.73		2	
709	59	+37.7	49.2	− 6.3	2.41	31	5	
710	21 00	+55.5	62.2	+ 6.5	0.08		4	
711	01	+46.4	55.7	− 0.6	0.18		0.36	
712	01	+67.3	71.0	+13.7	0.64	65	3	
713	02	+44.0	54.2	− 2.4	2.13	2	11	B 358
714	02	+43.0	53.3	− 3.2	0.06		0.24	
715	02	+52.2	60.0	+ 3.6	21.03		105	
716	03	+64.2	68.8	+11.4	4.88		15	
717	07	+41.1	52.7	− 5.1	4.50		21	Волокно b
718	07	+42.5	52.6	− 4.2		26	0.25	
719	08	+45.8	56.2	− 1.9	0.12		0.37	
720	09	+47.2	57.2	− 1.1	0.30		1	B 361
721	09	+39.4	51.8	− 6.6	2.32	16	5	
722	10	+43.3	54.[illegible]	− 3.9	0.18	2	0.18	
723	10	+61.1	67.6	+ 8.8	0.21	3	0.85	
724	11	+46.4	57.0	− 1.9	0.21	12	0.64	
725	12	+47.9	58.1	− 0.9	0.12		0.25	
726	14	+42.9	54.8	− 4.7	0.45	1	2	
727	16	+47.0	60.4	− 2.0	4.54	51	18	
728	16	+52.4	61.7	+ 1.9	0.34		2	
729	19	+50.6	60.8	+ 0.2	0.06		0.18	
730	20	+57.8	6[illegible].8	+ 5.4		15	17	Кольцеобразная c
731	21	+49.8	60.5	− 0.6	0.03		0.15	B 362
732	22	+48.7	59.8	− 1.5	0.12		0.49	B 363
733	22	+62.6	69.3	+ 8.8	0.52		2	
734	23	+50.4	61.1	0.3	1.10	64	1	
735	23	+49.3	60.4	− 1.3	0.21	63	0.64	
736	28	+44.7	57.9	5.1	0.46	47	1	
737	30	+47.5	60.0	− 3.7	1.62	47	5	
738	30	+5[illegible]	66.3	+ 4.0			0.24	
739	30	+6[illegible].7	70.0	+ 0.[illegible]	0.7[illegible]	4	3	
740	31	+53.0	61.3	+ 2.1	[illegible].07		4	B 364 b
741	32	+56.2	65.9	+ 3.2	0.03		0.15	Волокно
742	3[illegible]	+57.0	66.6	+ 3.7	0.06		0.24	
743	3[illegible]	+57.3	66.9	+ 3.8	0.06		0.24	Волокно b
744	35	+ [illegible]3.1	57.9	− 6.6	1.49	50	3	B 166
745	35	+55.7	65.9	+ 2.5	0.21		0.85	
746	37	+59.3	68.5	+ 5.1	0.79		2	
747	38	+43.9	58.8	− 6.0	0.00	72	0.40	
748	38	+57.4	67.3	+ 3.0	0.09		0.36	B 161 Волокно b
749	38	+49.2	62.1	2.6	0.52	51	1	Волокно b
750	38	+46.8	60.7	− 4.7	1.68	38	7	
751	39	+50.3	60.7	+ 2.8	0.03		0.12	B 165 Волокно b
752	41	+53.3	65.2	+ 0.1	0.7[illegible]		2	
753	42	+51.2	64.0	− 1.6	1.07	14	1	B 164
754	43	+48.0	62.0	− 2.6			0.25	Кольцеобразная c
755	44	+57.5	68.0	+ 3.1	0.15	36	0.36	
756	44	+59.2	69.1	+ 1.7			0.25	Кольцеобразно волокно d
757	45	+47.1	61.8	− 5.2	0.55	44	2	Волокно. В конце волокна диффузная туманность e
758	45	+59.9	[illegible]	+ 4.9		59	0.25	Кольцеобразная c
759	46	+50.6	61.8	+ 1.5	0.15		0.61	Волокно b
760	51	+50.2	68.0	+ 1.5	5.07	70	18	
761	55	+45.3	62.1	− 7.8			0.25	B 35[illegible] Кольцеобразная c
762	56	+58.1	69.7	+ 2.7	0.13		2	Кольцеобразная B 169, 170, 171 c
763	59	+52.4	66.8	− 2.3	0.82	44	2	

Key: a. Notes
b. Filament
c. Ring-shaped
d. Ring-shaped filament
e. Filament. Small diffuse nebula at end of filament

№№	α_{1900}	δ_{1900}	l_{1900}	b_{1900}	[illegible]	[illegible]	[illegible]	a Примечания [illegible]
764	22h00m	+70.8	81.2	+17.0	[illegible]		[illegible]	
765	01	+44.8	62.1	9.0	[illegible]		[illegible]	[illegible] b
766	03	+58.8	71.9	+ 2.8	0.12	[illegible]	0.49	[illegible] 174
767	11	+53.2	68.7	2.5	1.[illegible]	2	3	
768	10	+63.1	74.8	+ 5.5	2.22	[illegible]	11	
769	17	+62.1	74.1	+ 4.0	0.55		2	
770	23	+60.5	73.8	+ 2.8	1.43	2	6	
771	24	+59.2	73.4	+ 1.7	0.[illegible]		37	
772	27	+62.3	75.2	+ 4.1	3.57		11	
773	30	+59.2	74.5	+ 1.1	1.77		7	
774	30	+63.8	76.2	+ 5.3	4.30	57	[illegible]	
775	33	+56.5	73.1	− 1.4	0.18	80	0.57	
776	35	+71.6	81.8	+14.6	0.58	0	2	
777	42	+60.6	76.0	+ 1.8	8.58	71	12	
778	43	+52.2	72.5	− 5.8	1.10		4	
779	44	+56.9	74.7	− 1.5	0.30	39	0.01	
780	52	+62.0	77.1	+ 1.6				
781	53	+61.0	76.9	+ 0.6				
782	55	+69.0	80.7	+ 9.0	3.23	9	13	
783	59	+65.2	79.6	+ 5.2			0	
784	23 06	+46.1	73.5	−12.0	[illegible]		0.23	
785	08	+49.9	75.2	− [illegible]	27		0.83	
786	16	+66.9	81.8	+ 0.2	0.02	61	35	
787	17	+73.5	84.1	+12.4	0.75	7	0.01	
788	17	+70.4	81.1	+ 9.6	6.67		3	
789	26	+58.5	80.4	2.1	13.10		52	
790	33	+71.3	84.7	+10.0	3.32	12	13	
791	35	+63.2	82.7	+ 2.1			36	
792	42	+54.9	81.7	− 7.2	0.73		1	
793	51	+58.0	83.5	− 3.4	0.37		1	
794	52	+57.9	83.7	− 3.5			0.25	Глобула c
795	52	+59.1	83.8	− 2.5	0.27		1	
796	52	+61.3	84.2	− 0.2	3.22		1	
797	55	+68.7	85.6	+ 7.1	6.10	13	26	

Key: a. Notes c. Globule
b. Filament, globules

III. Structural Features of Dark Nebulae

§ 1. Introductory Remarks

By examining the photographs of the Milky Way in Ross's atlas, it is difficult to free oneself of the impression that, on the one hand, dark nebulae create the ragged structure of the Milky Way, as if it were devoid of any integrity, and on the other hand, that some features and quite definite regularities in their apparent distributions emerge in separate sections of the heavens, against a background of the seemingly chaotic distribution of dark nebulae. The same can be said in regard to the structural and morphological features of individual dark nebulae. Among the multitude of all the possible shapes, in this structural diversity, one can single out a number of characteristic elements and carry out somewhat of a grouping of the objects according to general criteria.

The revelation of the type and nature of the elements, as well as of the regularities in distribution and orientation of dark nebulae in separate regions of the heavens, is of interest even from the point of view of studying the dynamics of dark clouds. These structural features, in all likelihood, reflect the dynamic processes in the dark clouds, and are, as of now, the sole observable fact which furnishes us even scanty information on the movement and development of these objects.

We already know the values of many characteristics of dark /71
nebulae with sufficiently good approximation: average dimensions, masses, densities, dimensions and physical properties of their component particles, etc.. Thus, one can conceive, in the most general form, those possible dynamic processes and paths of development of dark clouds which can be encountered under the conditions of the interstellar environment.

All forces which affect the state of dark clouds can be conditionally (according to the results of their effect) divided into two groups. The first group includes forces which promote condensation and compacting of the matter in dark clouds, a decrease in the latters' dimensions, and the imparting of a more or less regular spherical shape to them. The second group includes forces which deform, destroy, and break up dark clouds into separate parts.

The forces of the first group include the gravitational forces of the dark cloud itself. The intrinsic potential should increase the density of the dark cloud because of the decrease in its dimensions. This process should be accompanied by an increase in the dimensions of the dust particles and the formation of meteoric bodies.

The radiation pressure of external stars acts in this same direction. If a dark cloud were surrounded on all sides by stars of high luminosity, then the latter could condense the dark cloud with the pressure of its radiation, since the dimensions of the particles and the density of the nebula create a basis which is conducive to this process.

One should name the differential effect of the gravitational potential of the entire Galaxy first and foremost among the forces which belong to the second group. It should be considerable with respect to dark nebulae, since their dimensions are considerable, and their densities are comparatively insignificant. It follows from the formula, derived from the well-known Oort's expression

$$\ln\frac{R_1}{R_2} = A(t_1 - t_2)\sin 2(l - l_0),$$

where R is the radius of the dark nebula, that a twofold increase in the dimensions takes place in the direction of the plane of the Galaxy in a period of approximately 10^7 years [41]. Thus, the elongation of dark nebulae along the plane of the Galaxy, which takes place as a result of differential galactic revolution, should be appreciable.

The idea of the turbulent nature of motion of the matter in dark clouds suggests itself with the observation of the complex vortical and filamentous shapes of the elements of dark nebulae. Since favorable conditions for the switch of the laminar flow of the dust environment to a turbulent flow should be created in interstellar space (transit of stars through the cloud, collision of clouds, radiation pressure of nearby star, stagnation of interstellar environment, etc.) and, in addition, since the rough evaluation of Reynold's number for the dust gives about 10^9 [42], the assumption of the motion's turbulence is all the more plausible. However, if it is nevertheless possible to draw some conclusions using the evaluations of fluctuations in the surface brightness of nebulae in the case of light, diffuse nebulae, serious difficulties are encountered during the study of the question of turbulence of motion in dark nebulae. It is impossible to evaluate density here or determine the velocity of individual components of dark nebulae.

Thus, forces of different natures and origins act on a dust cloud: in some cases—promoting condensation and reduction in dimensions, and in others—deformation, destruction, and fragmentation. Based on general considerations, it is very /72 difficult to present a picture of the total resultant effect of these forces. Here, the criterion of gravitational stability does not help, since it does not take into consideration radiation pressure and such sporadic factors as transit of a star through a cloud, collision of clouds, stagnation, etc.. Our material and methods do not make it possible to examine closely the questions of the kinematics of the elements of dark nebulae; however, one can form an opinion about the dominant factors which affect the structure of dark nebulae according to the statistics of data on the orientation of the elongations and elements of dark nebulae.

The study of the structural features of dark nebulae is interesting for the accomplishment of some grouping, if not for the purpose of a classification which reflects the path of evolution of dark clouds, then, in any case, to facilitate the study and revelation of characteristic features.

It seems to us that the best of the methods of determining shapes and revealing elements of dark nebulae known to us is the study of these objects visually, directly on photographs. In spite of the known subjectivity of this method, it nevertheless can provide material which satisfies the requirements in some respects. Wolf's method, as we have already indicated, is less effective for these purposes, since the details of the outlines of the dark nebulae are lost with its utilization, because of many inevitable averagings.

§ 2. Different Shapes of Dark Nebulae

a) Small, round, very dark formations—so-called globules, should be mentioned first and foremost among the structurally interesting dark nebulae. They are observed in the overwhelming majority of cases against a background of light diffuse nebulae and bright star clouds, where they are easily detected because of their regular shape and strong blackening.

Bok and Reilly first gave them attention in 1947 [43] against the background of Messier 8, the star clouds of Ophiuchi and Sagittarius, and others. It was emphasized further in the studies of G. A. Shain and V. F. Gaze [27], V. G. Fesenkov and D. A. Rozhkovskii [44], and others, that the frequent presence of globules against their background is a characteristic feature of diffuse nebulae. The average apparent size of the globules is determined as about 4', and the true radii, between 0.03 and 0.4 parsecs, according to the data of Bok and Reilly. Ye. L. Ruskol [36] gives a value of 0.12 parsecs for the average radius; V. G. Fesenkov and D. A. Rozhkovskii give 0.15 parsecs.

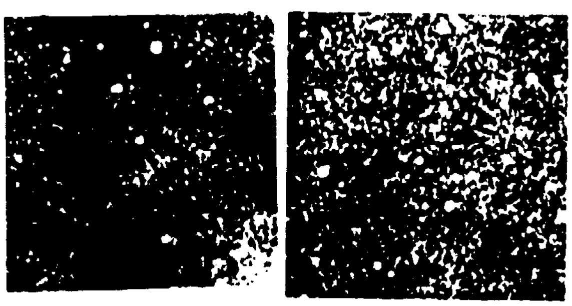
V. G. Fesnkov and D. A. Rozhkovskii, investigating enlarged negatives, established the presence of a multitude of globules against the background of some light, diffuse nebulae and, having analyzed their configuration among themselves and with respect to the inclusions of dark matter, arrived at the conclusion that globules are physically connected with diffuse nebulae, forming a component part of the latter. But, on the other hand, it is not precluded that globules are simply projected on the background of diffuse nebulae, without having a physical connection with them.

Ye. L. Ruskol, proceeding from the position that not a single star is projected onto the globules, determined the maximum distance of the globules from the observer. It is equal to 230 parsecs. Thus, the space in which we can detect globules which are not against a background of diffuse nebulae proves to be quite small.

We did not give ourselves the purpose of singling out globules in our catalog and studying them separately. This is because, first, it seems to us that there is still not an exacting definition of the concept of a "globule", since dark nebulae are often encountered which are distinguished from the globules described above by only slightly larger dimensions, and this is insufficient for a conclusion about the physical difference /73 between them. On the other hand, very dark black "points" of noncircular shape are encountered, and, in general, the symmetry of globules is conditional to some degree. Globules of more or less blurred, elliptical, and irregular shape are encountered, and, in addition, photographs of some globules on a 100-inch reflecting telescope indicate the filamentous structure of the latter [45]. Second, it is impossible to consider the scale of Ross's atlas fully appropriate for this purpose.

Globules are nearly opaque, which suggests that the phenomenon of condensation of interstellar matter of a high degree is observed. But this fact was determined, which was of interest, rather from the point of view of cosmogony. According to the idea stated by Whipple [47] and Spitzer [46], globules can be regarded as a stage which precedes the formation of stars by means of the condensation of interstellar matter. A dark cloud, under the influence of radiation pressure from all sides, as well as the intrinsic force of gravity, should condense and be reduced to small dimensions, which is observed in the form of a globule. The stated evolutionary path, if it is more or less uninterrupted, requires that a large number of globules be observed in nature, and, in general, dark nebulae of small dimensions should prevail, unless we want to assume a discontinuity between the evolution of stellar and diffuse components. The stated position is supported by some results of the present investigation (see chapter IV).

b) Another structurally interesting type of dark nebula are individual dark filaments, which are observed primarily against a background of bright star clouds. One can cite the dark nebulae from our list under Nos. 54, 719, 757, 760, and others as an example. We provide photograph No. 1, which does not require explanation, for the most typical filaments.



Photograph 1

It is very difficult to detect such dark filaments if they are not against the background of bright star clouds, since the breadth of the filament is sometimes less than the average distance between stars, and the danger exists of taking an apparent dark line for a filament.

As we know from the literature, dark filaments have not been studied specially, and, therefore, it nevertheless seems to us advisable to list some information about them, although it is quite meager.

Dark filaments are sometimes observed separately, while, /74 in some cases, they are projected onto a more grayish dark nebula. They often have a zigzag shape and are rarely observed as a straight line. The breadth of such filaments is equal, on the average, to 7', while the length is from 0.5° to 2.5°. It is clear that dark filaments should be located comparatively close to us, or that they are young formations. One can roughly determine the distance to dark filaments, based on considerations similar to those which we had in the case of globules [36]. One can determine at what distance a filament of average apparent dimensions should be located in order that not a single star is projected onto its surface. The maximum distance, according to our rough determination, turns out to be 250 parsecs.

In view of the extremely small number of dark filaments known to us, we could not detect any regularities in the shapes and distribution of such objects. Neither were characteristics detected which indicate a connection with the closest dark or light nebulae, or with the stellar background. Dark filaments are usually clearly delineated against the background of light, diffuse nebulae, and, therefore, the study of the photographs from G. A. Shain and V. F. Gaze's atlas of diffuse nebulae [48] is promising in this aspect.

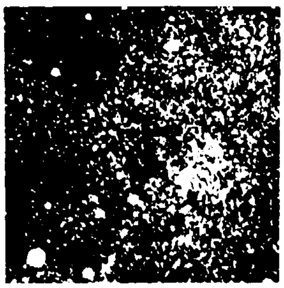
Some dark nebulae make it possible to draw conclusions, although somewhat controversial ones, about the connection of globules with dark filaments.

Figure 6 is reproduced from Barnard's atlas. Separate

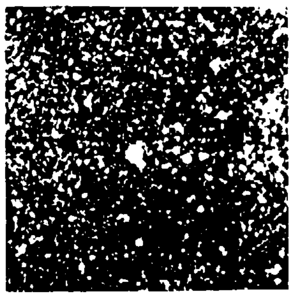
Figure 6

centers of condensation are noted here. They appear quite dark in the photographs. This phenomenon, i.e. the break-up of a dark filament into separate globules, can be noted especially easily on the example of dark nebula No. 352. Separate centers of condensation in the dark filament are clearly observed in photograph 2. Here, globules which are equal in magnitude and blackening, five in number, located at nearly an equal distance /75
from each other, are connected by thin, black lines, which are undoubtedly real. Several globules, similar to the former in dimensions and blackening, are located near this filament. One can still indicate some dark nebulae in which this phenomenon is observed to a greater or lesser extent: Nos. 553, 560, 763, 766, and others. Groups of globules are also found, configured somewhat regularly, where the connecting lines have, however, already disappeared.

c) Dark nebulae, which can be conditionally called ring-shaped, are undoubtedly interesting from the structural point of view. Nebula number 755, a depiction of which is presented in photograph 3, is typical in this respect.



Photograph 2



Photograph 3

A thin, dark ring, the apparent radius of which is equal to 33.5', encircles the star $81\pi^2$ Cygni ($\alpha=21^h43^m6$; $\delta=48°51'$), of apparent stellar magnitude of 4.26 and spectral class B3. The star is located in the center of this ring, which is difficult to consider accidental. The picture of the external view resembles a "dark planetary nebula". If the star and nebula are taken as a single system, then the true radius of this ring would be equal to 2.5parsecs. It is located at a distance of 250parsecs from us.

One can still point out several other dark nebulae which more or less resemble that described above. Bright stars are not found at their centers, and, besdies, they are more irregular.

The existence of dark, ring-shaped nebulae was indicated by Morehouse as early as 1927 [40]. He noted a dark ring, similar to the "Bird's Nest", in the northwestern part of the nebula "America". Similar nebulae have been indicated in the region of Lyra and near χ Cygnus. Morehouse only established the existence of a ring-shaped dark nebula, but drew no conclusions whatsoever on the origin and nature of such a formation.

d) During the study of the features of the shapes of dark nebulae, we should take into account the position that the stellar background, which is itself non-uniform, strongly affects the apparent shape of dark patches. We divided dark nebulae into several groups according to morphological outlines, but by no means for the purpose of classification. This division is given in table II, and the number of dark nebulae which belongs to one group or another is given, in per cent.

The majority of regular dark nebulae has the shape of an ellipse. This ellipticity is sufficiently well-expressed in the majority of cases, but there are cases when it occurs after smoothing.

TABLE II /76

a [illegible]	b [illegible]	c [illegible]
1. Неправильные d	50.0	e [illegible]
2. [illegible] f	2[illegible]9	g [illegible]
3. Волокна h	9.1	i [illegible]
4. [illegible] j	7.3	k [illegible]

Key:
a. Types of dark nebulae
b. Number of dark nebulae, in %
c. Notes
d. Irregular
e. Both dark nebulae of indefinite, complex shape and triangular, polyhedral, and filamentous nebulae are joined in a group
f. Elliptical
g. In addition to elliptical nebulae, dark nebulae of circular shape also appear in the group
h. Filaments
i. Both individual dark filaments and narrow, uneven dark nebulae, as well as dark canals of large dimensions, appear here.
j. Globule-shaped
k. These nebulae are somewhat larger in size than the globules, but they resemble the globules in their high level of blackening

Dark filaments, as well as long, dark canals, are the most extreme form of elongated nebulae, from the point of view of their shape. One should conclude that the elongation is observed, for the most part, in nebulae of average and small dimensions.

We distinguished dark nebulae of filamentous structure individually. Here, of course, it is impossible to speak with such confidence as in the case of diffuse nebulae, since the filamentous nature is expressed very weakly.

§ 3. Some Structurally Interesting Regions of the Milky Way

Some regions of the Milky Way display a series of structurally interesting features, in terms of the distribution of dark nebulae in them. The characteristics of these regions seem pertinent to us. The first thing to do is indicate the two opposite directions, ℓ=340°-350° and ℓ=130°-140°, which roughly coincide with the directions to the center and anti-center of the Galaxy.

First, a considerable concentration of dark nebulae is noted here (especially in the direction 340°-350°), which is corroborated by the presence of strong light absorption in these directions, which begins comparatively close to the sun [53].

Second, asymmetry is observed in the apparent distribution of dark nebulae relative to the galactic equator. In the direction ℓ=340°-350°, dark nebulae are concentrated primarily on the northern side of the galactic equator, and in the direction ℓ=130°-140°—on the southern side.

By carefully examining photograph No. 30 in Ross's atlas, one can note the following peculiarity. A long, narrow, grayish line connects dark nebulae Nos. 69, 73, 85, 105, and 106. This slightly curved line begins about $\alpha=4^h26^m$, $\delta=24°7'$, and is a continuation of the darker long filament under Nos. 46 and 54, /77
and extends to the northwest. This dark line, which is roughly 15° long, the reality of which is difficult to doubt since it is often repeated in photograph 31 as well, is represented schematically in figure 7. It should be located very close to us, or be a relatively young formation, for it is impossible to maintain such an elongated shape for long. Most likely, one can expect that it is a trace (remnant), which reflects in itself some process in which the dark nebulae indicated above took part. Similar phenomena can be noted in dark nebulae Nos. 264 and 273 in Ross's photograph No. 3.

One should also mention the row formed by the dark nebulae in the constellations Sagitta and Vulpecula. The dark nebulae under Nos. 574, 585, 589, 298, 617, 627, 634, 654, 656, and 658, which differ little in magnitude and blackening, are located in a row on a line which is nearly parallel to the galactic equator,

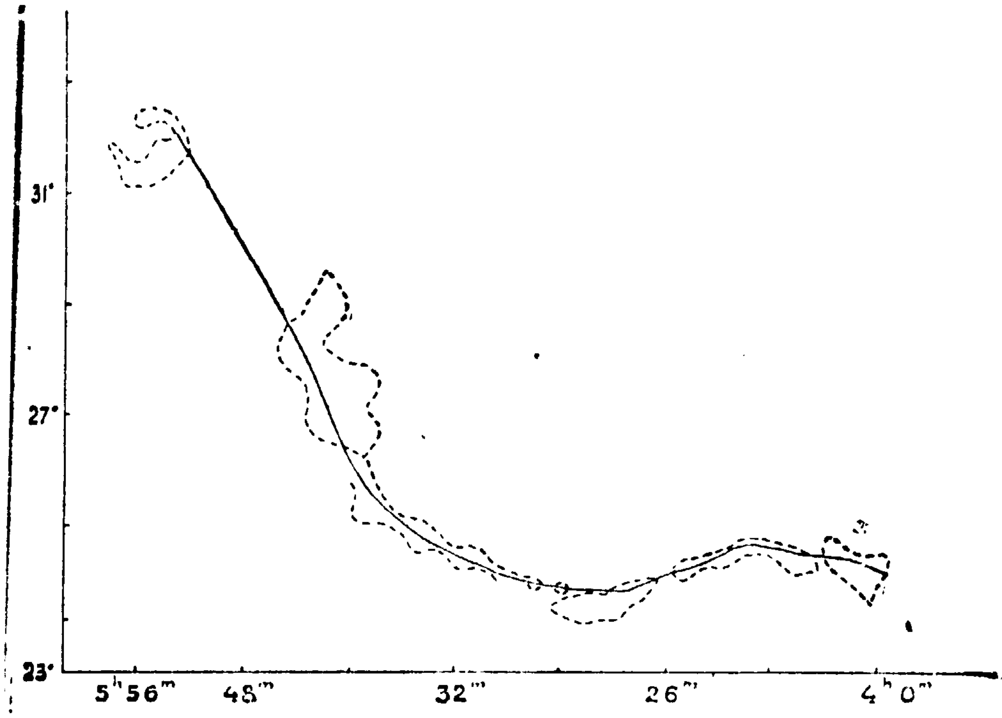


Figure 7

and create the impression of a long, dark zone, divided into separate dark nebulae. This phenomenon is represented schematically in figure 8.

A definite regularity in the configuration and orientation of dark nebulae is observed in some regions of the Milky Way. For example, one can point out the region northwest of ρ Ophiuchi. The dark nebulae located northwest of the stars ρ Ophiuchi, 22, α, δ, γ Scorpius, HD 148579, and others, form a group, the configuration and orientation of the elongations of which draw attention to themselves. Beginning from 22 Scorpius, dark zone No. 264 stretches 5°, and subsequently divides into distinct dark nebulae of small dimensions, the majority of which are oriented almost parallel to the indicated zone. North of the dark nebula No. 264, near the star BD-24°12684, another zone, /80
Nos. 256, 273, begins, which differs little (by 12°) from the first in direction of orientation. The described group of dark nebulae is represented schematically in figure 9. The dashes indicate the direction of the elongations of the dark nebulae, and their lengths are proportional to the weights of the latter. The roughly equal orientation of the dark nebulae of this group is evident. The primary direction of their orientation forms an angle with the galactic equator which is roughly equal to 35°.

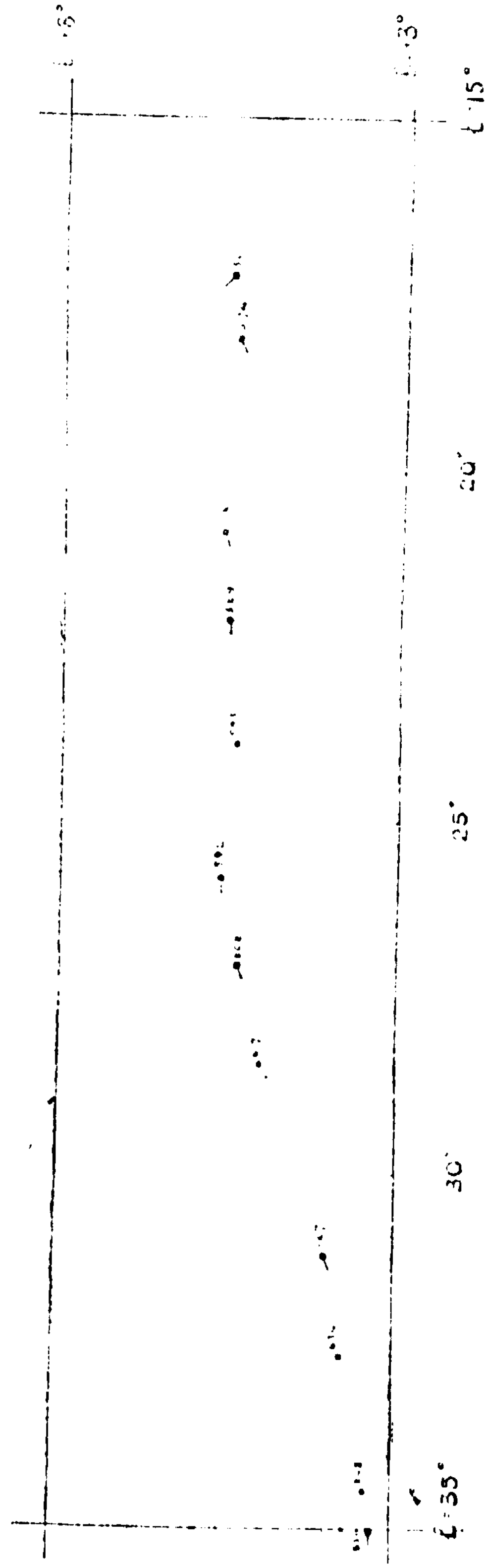


Figure 8

/79

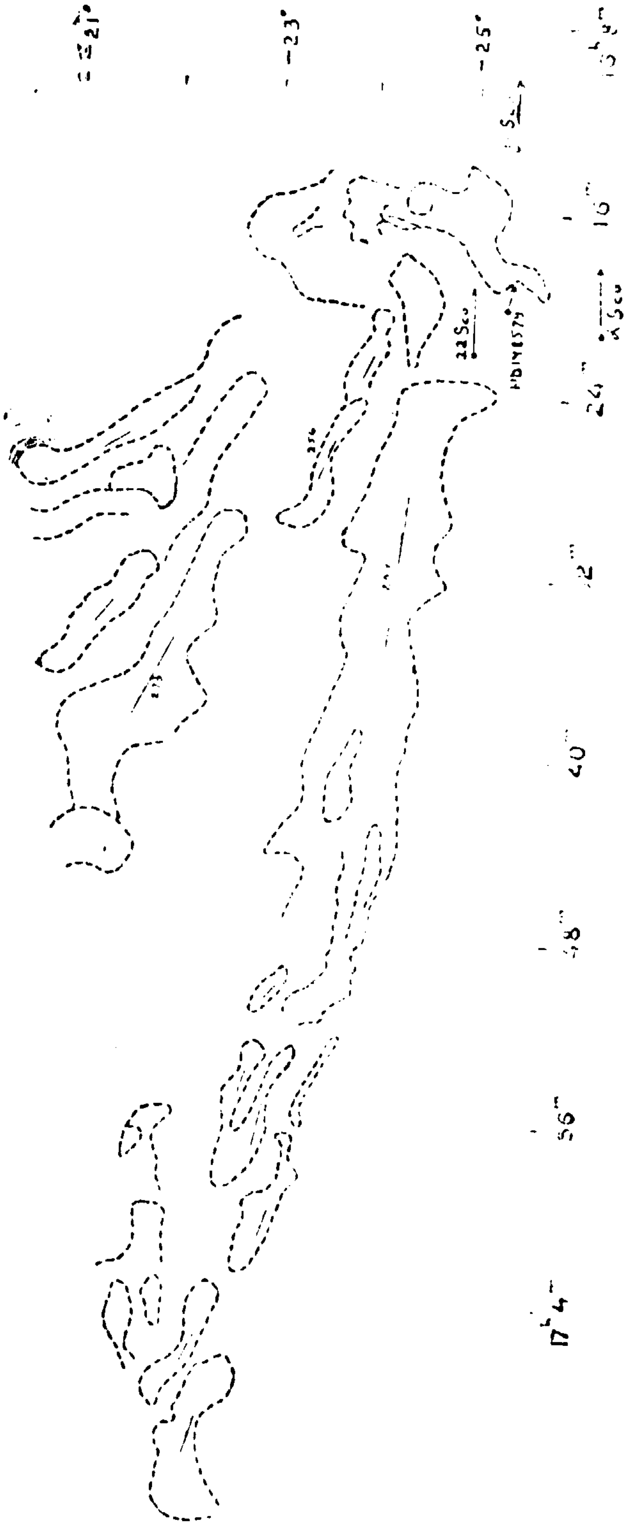


Figure 9

The following should be added to what has been said. N. E. Gould [49] determined the movement of stars, located at the edge of the indicated dark zone: α,σ,22 Scorpius and HD 148579, relative to the system of dark nebulae.

It is noteworthy that the directions of movement of these stars coincides well with the direction of the dark nebulae in this region. The directions of movement of these stars are shown with arrows in the drawing. The average distance to these stars is equal to 100 parsecs. It should also be noted that, according to the investigations of R. Müller [50], the effect of these dark clouds on the number of stars begins from the distance 100 parsecs. Thus, the existence of some connection between the described group of dark nebulae and the group of bright stars located in the vicinity of the named dark nebulae seems likely.

IV. The Statistics of Dark Nebulae

§ 1. Introductory Remarks

By making use of the tentative catalog of dark nebulae, one can carry out a series of statistical investigations, which, on their part, can furnish information about some properties of dark clouds. The construction of functions of distribution of dark nebulae according to galactic coordinates, position angles of orientation, apparent surface areas, etc., is interesting.

Statistical investigations of the system of dark nebulae are well-known from the literature, but our material and methods of approach to the problem differ from those used before in that we make use of measured values of the apparent characteristics of dark nebulae, the reality of which, within the limits of accuracy indicated above, cannot be doubted.

Some conclusions we obtained coincide with the earlier-known results of other authors, but we will list them all the same, considering it pertinent right here to corroborate some already-established facts, which is not at all uninteresting, insofar as our results were obtained on new material, which differs from the rest. Other conclusions are, in essence, new, and are surely of interest.

§ 2. Distribution of Dark Nebulae according to Galactic Coordinates

If we arrange the centers of the dark nebulae on the map with the corresponding weights, one can perceive the general

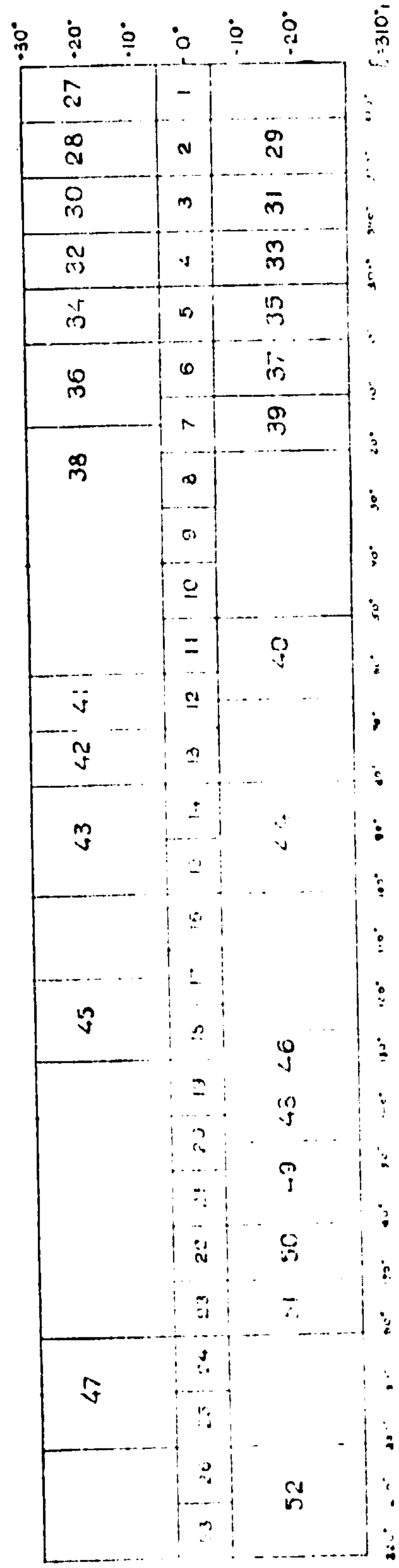

+30°
+20°
+10°
0°
-10°
-20°
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Figure 10

picture of the apparent distribution of dark nebulae according to galactic coordinates. The galactic zone we examined, bounded by galactic latitudes b=±25° and galactic longitudes from ℓ=0° to ℓ=220° and from ℓ=310° to ℓ=360°, was divided into 53 areas, the location of which is presented in figure 10. /82

Areas Nos. 1-26 were selected strictly in the galactic zone, being located along the equator and bounded by galactic latitudes b=±5°. Thus, each of them encompasses a 10° x 10° area in the heavens.

The remaining areas are located on the north and south sides of the galactic equator. Their dimensions are unequal and they are not symmetrical relative to the galactic equator, which was caused by the apparent non-uniform distribution of the dark nebulae. It is clear that the methods of dividing the zone being studied into separate areas has no meaning whatsoever for statistical calculations similar to ours.

The weighted mean values of direct ascension and declination for the area were calculated for the dark nebulae appearing in a certain area, according to the formulas:

$$\alpha = \frac{\sum p\alpha}{\sum p}, \quad \delta = \frac{\sum p\delta}{\sum p} \qquad (1)$$

For the purpose of verification, the calculations were carried out simultaneously according to equatorial and galactic coordinates. The weights P were assigned average values, which are the sums of the weights for all of the dark nebulae appearing in a given area:

$$\sum p_i = P \qquad (2)$$

Values of the following characteristics are given in table III for each area: numbers of areas, numbers of dark nebulae, total weights P, weighted mean equatorial coordinates α and δ, and also the weighted mean galactic coordinates ℓ and b.

The investigation of the distribution of the total weight P according to the galactic longitude ℓ, and its comparison with the distribution of the coefficient of absorption a according to the longitude ℓ, are of definite interest.

This dependence is presented in figure 11 (solid curve).

P is an abstract magnitude, and our curve has a relative nature. The curve is constructed according to the data in table III. Smoothing was carried out at three points by means of averaging, i.e. for each point on the curve, an average value of the given point and the two adjacent points was taken.

We noted two maxima here, the larger of which coincides with the direction ℓ=340°-350°, i.e. with the direction towards the center of the Galaxy, and the smaller—towards the anticenter: ℓ=130°-140°. In the remaining directions, the course of the curve is uniform. Granted, there are some deviations, but they have a random nature and can not be attributed to peculiarities of the microstructure of the distribution.

The broken curve, which designates the function of the coefficient of absorption a_0 according to galactic longitudes ℓ, is taken from the study of B. V. Kukarkin [19], and we constructed the dotted curve according to the data of P. P. Parenago's map [22], by means of picking out our regions on this map and calculating the average values of a_0 for different values of ℓ.

The coincidence of these curves is satisfactory, which should have been expected, based on the fact that wherever there is more interstellar matter, there is greater absorption. However, this coincidence also speaks in favor of the fact that the magnitude of P sufficiently reliably characterizes the amount of interstellar matter close to us.

For construction of the curve, values of P throughout the zone b=±30° were taken for a given ℓ, so that these curves would characterize a broad galactic zone with latitudes b= ±30°. /83

It is interesting to construct a similar curve for a narrow galactic zone with latitudes b=±5°. It is represented in figure 12 (solid curve). The second maximum in the direction of the anticenter of the Galaxy no longer stands out on it, i.e. the impression is created that the total weight of the dark matter is maximally concentrated in the direction of the center of the Galaxy and falls in both directions along ℓ, reaching a minimum somewhere near the anticenter. /84

Thus, the distribution according to ℓ of the total weight of the dark nebulae located in the narrow galactic zone has a regular nature, i.e. it agrees well with the notion that the spatial density of dark nebulae falls from the center of the Galaxy along its radius. /86

As regards dark nebulae located outside the narrow zone b= ±5°, they should be a reason for the appearance of a second maximum in the direction of the anticenter of the Galaxy. We will further see that a more substantial difference exists between these two groups of dark nebulae.

TABLE III

№№	$\bar{\alpha}_{1900}$	δ_{1900}	l	[illegible]	n	P
1	$16^h 51^m$ [illegible]	[illegible]	[illegible]	+ [illegible]	[illegible]	[illegible]
2	17 25.80	− 20.02	320.12	+ [illegible]	30	[illegible]
3	17 51.[illegible]	− 21.54	335.[illegible]	− [illegible]	31	[illegible]
4	16 10.[illegible]	13.09	344.[illegible]	− 0.20	27	[illegible]
5	16 20.21	− 3.23	355.40	+ 1.57	21	[illegible]
6	[illegible]	+ 4.29	4.02	+ 0.47	[illegible]	245.[illegible]
7	[illegible] 13.[illegible]	+ 12.42	14.04	[illegible]	13	[illegible]
8	19 [illegible]	+ 21.80	24.56	0.55	22	161.[illegible]
9	19 53.[illegible]	+ 28.17	33.22	+ 1.41	20	[illegible]
10	20 27.17	+ 38.20	45.48	1.[illegible]	[illegible]	[illegible]
11	20 50.[illegible]	+ 48.74	57.31	+ [illegible]	[illegible]	177.[illegible]
12	21 30.32	+ 51.48	63.41	− 0.[illegible]	[illegible]	70.[illegible]
13	22 30.[illegible]	+ 60.26	75.20	− 1.84	[illegible]	72.8[illegible]
14	23 57.[illegible]	+ 61.00	85.07	+ 0.40	11	201.50
15	1 16.07	+ 62.86	94.33	+ 1.21	13	163.00
16	2 [illegible]	+ 60.08	102.10	+ 0.34	[illegible]	45.[illegible]
17	3 49.78	+ 33.24	[illegible]	+ 0.9[illegible]	6	79.[illegible]
18	4 26.[illegible]	+ 64.07	127.61	0.24	11	80.01
19	[illegible] 53.[illegible]	+ 37.20	[illegible]	− 1.88	10	81.[illegible]
20	5 27.20	+ 20.04	[illegible]	0.42	7	116.[illegible]
21	5 56.[illegible]	+ 22.05	153.59	+ 1.21	[illegible]	50.0
22	6 9.87	+ 15.30	16[illegible].01	+ 0.74	14	15[illegible]
23	6 28.[illegible]	+ 4.55	17[illegible].59	− 0.50	11	71.40
24	6 56.[illegible]	− 2.30	18[illegible]	+ 3.09	10	71.[illegible]
25	7 12.[illegible]	12.96	195.22	+ 0.0[illegible]	[illegible]	132.0
26	7 25.21	22.24	20[illegible].61	[illegible]	[illegible]	14[illegible]
27	10 25.23	[illegible]3.70	[illegible]	+ [illegible]	23	8[illegible].77
28	10 [illegible]	[illegible]	32[illegible]	[illegible]	41	114.92
29	17 5[illegible].95	− 32.85	[illegible]	− [illegible]	15	52.85
30	17 9.12	− 15.61	33[illegible]	[illegible]	27	195.85
31	18 29.04	− 25.20	330.[illegible]	[illegible]0.30	[illegible]	10[illegible].71
32	17 16.57	− 0.88	349.[illegible]	+ 14.40	10	571.[illegible]
33	18 43.50	− 16.28	345.01	8.30	22	107.8[illegible]
34	17 51.70	− 0.33	354.33	+ 0.80	10	195.[illegible]
35	18 [illegible]	[illegible]0.21	354.06	7.57	15	40.01
36	18 24.[illegible]	+ 13.91	10.38	+ [illegible]0.01	3	7.0[illegible]
37	19 34.[illegible]	+ 0.71	7.1[illegible]	− 11.0[illegible]	10	103.[illegible]
38	18 [illegible]7.[illegible]	+ 10.04	10.00	+ [illegible]	8	[illegible]
39	19 [illegible]8.[illegible]	+ 8.33	13.[illegible]	[illegible]0.3	1[illegible]	32.2[illegible]
40	2[illegible] 4[illegible]	+ 4.51	50.43	7.[illegible]	6	[illegible]
41	21 [illegible]	+ 50.28	65.21	+ 8.0[illegible]	15	71.[illegible]
42	22 11.2[illegible]	+ 65.75	72.[illegible]	+ 7.[illegible]	5	33.0[illegible]
43	23 [illegible]	+ 70.96	83.94	+ 0.32	14	173.01
44	1 1.[illegible]	+ 51.98	95.15	− 0.97	[illegible]	17.0[illegible]
45	5 13.00	+ 50.04	121.33	+ 12.5[illegible]	8	25.70
46	3 5[illegible].01	+ 30.80	12[illegible].72	− 10.7[illegible]		[illegible]
47	7 2[illegible]	[illegible].04	[illegible]	+ 7.[illegible]8	[illegible]	23.0[illegible]
48	4 3[illegible]	+ 27.05	1[illegible].30	[illegible].62	[illegible]	287.50
49	5 [illegible]	+ 17.[illegible]	153.04	11.47	10	121.00
50	5 35.[illegible]	+ 8.[illegible]	16[illegible].55	− [illegible]	1[illegible]	91.[illegible]
51	5 5[illegible]	− 1.8[illegible]	17[illegible].81	11.7[illegible]	[illegible]	2[illegible]8.1[illegible]
52	7 0[illegible]	25.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
53	7 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

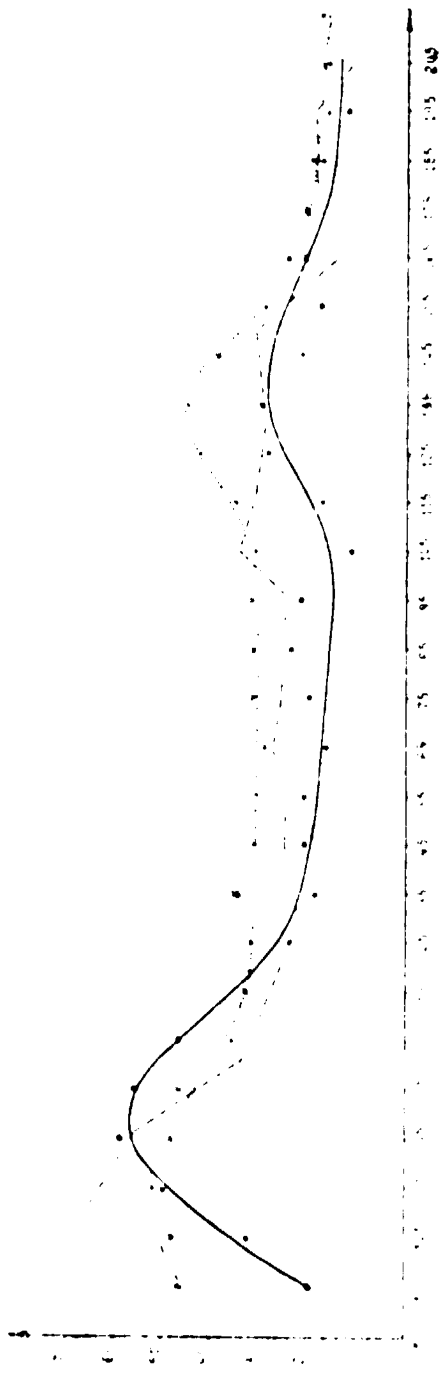

Figure 11

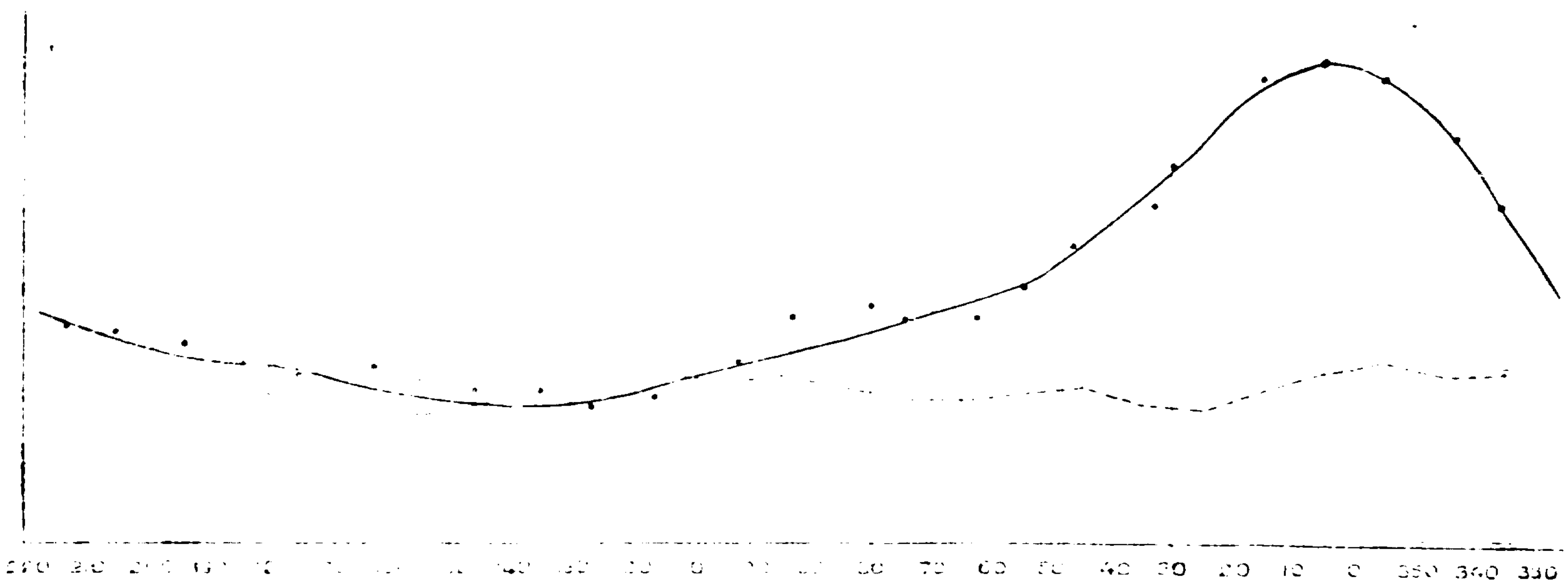

Figure 12

The broken curve in figure 12 was constructed according to the data of M. A. Vashakidze [32]. It depicts the function of light absorption according to galactic longitude, derived according to color surpluses of long-period cepheid variables. The noncoincidence of these curves is explained by the fact that visible dark nebulae are located close to us.

The tentative catalog of dark nebulae makes it possible to determine the position of the plane of symmetry of the dark nebulae. In the study of Ye. K. Kharadze [7], there is an indication of the existence of some asymmetry of dust matter relative to the galactic equator, expressed in the reddening of starlight. Analyzing Captein's catalog of indicators of the color of 14,000 stars in 43 areas, Kharadze arrived at the conclusion that the absorption of light is greater on the northern side of the galactic equator than on the southern side. The indicated asymmetry increases with an increase in galactic latitude, <u>i.e.</u> asymmetry is almost absent in the narrow galactic zone $b=\pm7.5°$; it becomes appreciable in the zone $b \pm 13°$, and is expressed definitely in the zone $b=\pm18°$. The author also notes the important role of absorbing clouds close to us in the appearance of the indicated asymmetry. Consequently, the determination of the position of the plane of symmetry of the dark clouds in space is of interest. In the case of the non-coincidence of this plane with the equator of the Galaxy, we obtain corroboration of Ye. K. Kharadze's conclusion on the asymmetry of distribution of dark matter.

On the other hand, the importance of the indicated task is brought about by the following circumstances. The apparent distribution of dark nebulae can not affect the apparent position of the plane of symmetry of other celestial objects, since it introduces distortion of a systematic nature.

We will cite the study of K. A. Barkhatova, relative to open stellar clusters [51], as an example. She arrived at the conclusion that the plane of greatest concentration of diffuse stellar clusters is inclined towards the plane of the Galaxy at an angle:

$$i = -2°7'. \qquad (3)$$

This was correctly interpreted by K. A. Barkhatova as a result of the noncoincidence of the plane of symmetry of the dark nebulae with the galactic equator.

The determination of the position of the plane of symmetry of the dark nebulae can aid in the improvement of results in the calculation of light absorption, according to the method developed by P. P. Parenago [16], in which it is assumed that the plane of symmetry of the dark nebulae, i.e. the plane of greatest concentration of light-absorbing matter, coincides with the equator of the Galaxy.

By itself, the distribution of dark nebulae relative to the galactic equator is not devoid of interest, irrespective of other questions. In light of the problem of interaction between the stellar and diffuse components of our Galaxy, this determination can serve as material for the study of some questions related to dynamic and kinematic problems of our Galaxy, of course with regard for the fact that we have limited data on the dark nebulae located only comparatively near the sun. /87

We conducted the determination of the position of the pole of the plane of symmetry of the dark nebulae according to Newcombe's method [52]. The calculation was carried out with four symbols with regard for the weights P for α and δ. The coordinates of the pole of the plane of symmetry of the dark nebulae, according to our calculations, turned out to be the following:

$$\left.\begin{array}{l} A_0 = 186°5', \\ D_0 = +30°6', \end{array}\right\} \qquad (4)$$

$$i = 4°. \qquad (5)$$

As is evident, these planes are inclined towards each other, granted, at a slight angle, but the noncoincidence is there, and has a magnitude which cannot be disregarded during the study of some questions of stellar astronomy.

Figure 13 represents the galactic zone, on which the weighted mean coordinates ℓ and b are drawn. The magnitudes of the squares correspond to the total weights P. As is evident, the system of dark nebulae is planar, with a well-expressed concentration in the plane of the Galaxy. 65% of all the dark nebulae are located in the narrow zone with galactic latitudes of ±5°.

The careful examination of the location of the points in figure 13 suggests that the apparent distribution of dark nebulae represents the combination of two planar systems, one of which lies strictly in the galactic zone, and a second, inclined towards the first at a certain angle which, being projected onto the heavens, creates a sinusoidal curve.

Actually, we will group those dark nebulae, the plane of symmetry of which coincides with the plane of the Galaxy, into one group—I. The dark nebulae appearing in this group I were located in the narrow galactic zone included within ±5°, according to galactic latitude. As an exception, we had the opportunity to expand this zone to $b=\pm10°$ in the direction of the galactic center from $l=320°$ to $l=350°$. An increase in the width of more than $\pm10°$ removes the plane of symmetry of group I from the position which coincides with the plane of the Galaxy. All of the remaining dark nebulae are grouped into another group—II.

The distribution of the dark nebulae in group II is presented in figure 14. The circles on the drawing designate the average galactic latitudes of the stars in spectral class B which are brighter than 5.25 stellar magnitudes, which probably belong to the local system. This picture of distribution is borrowed from Shapley's study [34]. The coincidence of the distribution of the nebulae with these stars is evident, which can not help but view as a fact which confirms the presence of a connection between the dark nebulae in group II and the stars in spectral class B which belong to the local system.

Corrections for the coordinates of the pole of the Galaxy were calculated for group I by the method of P. P. Parenago [54]. They proved to be insignificant, and almost did not change the position of the pole.

For $\Delta\Omega$ and Δi, we obtained the following values:

$$\Delta\Omega = 0.06°;\ \Delta i = 0.05°. \tag{6}$$

Thus, there is no doubt that the dark nebulae in group I are located symmetrically relative to the galactic equator. /89

With regard to the dark nebulae in group II, a different picture is observed here. The determination of the position of the pole of the plane of symmetry for this group was also carried out by Newcombe's method. The coordinates of the pole we calculated turned out to be the following:

$$\begin{aligned} A_c &= 178°42', \\ D_c &= +32°19', \\ i &= 10°34'. \end{aligned} \tag{7}$$

If (7) is compared with the coordinates of the pole of Gould's zone, then the coincidence must be considered satisfactory, taking into account the fact that there is considerable disagreement in the establishment of the coordinates of the pole of Gould's zone.

Thus, our material corroborates the existence of asymmetry in the distribution of dark matter. It seems to us that the dark nebulae close to us, which create a definite group in the

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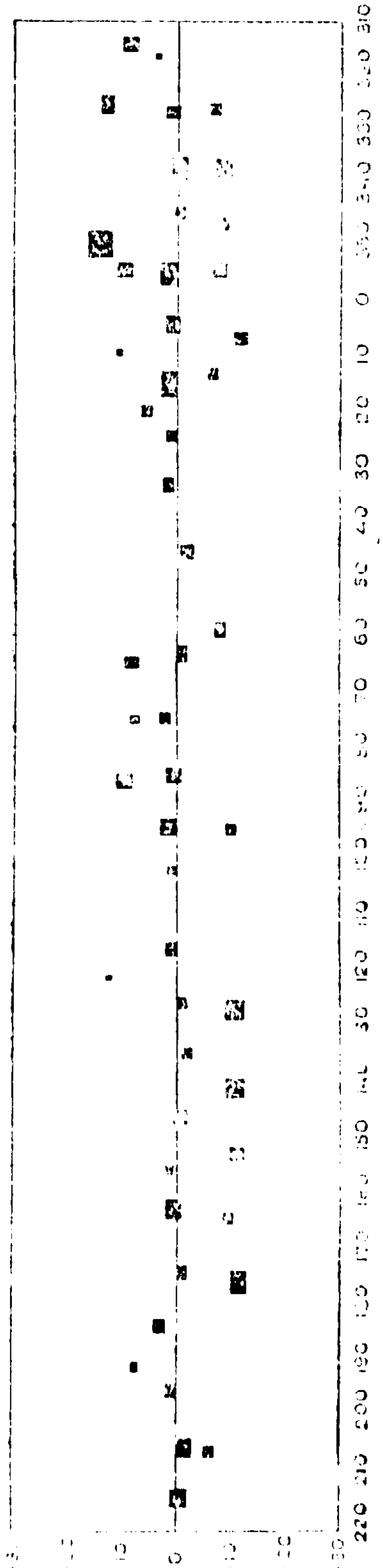

Figure 13

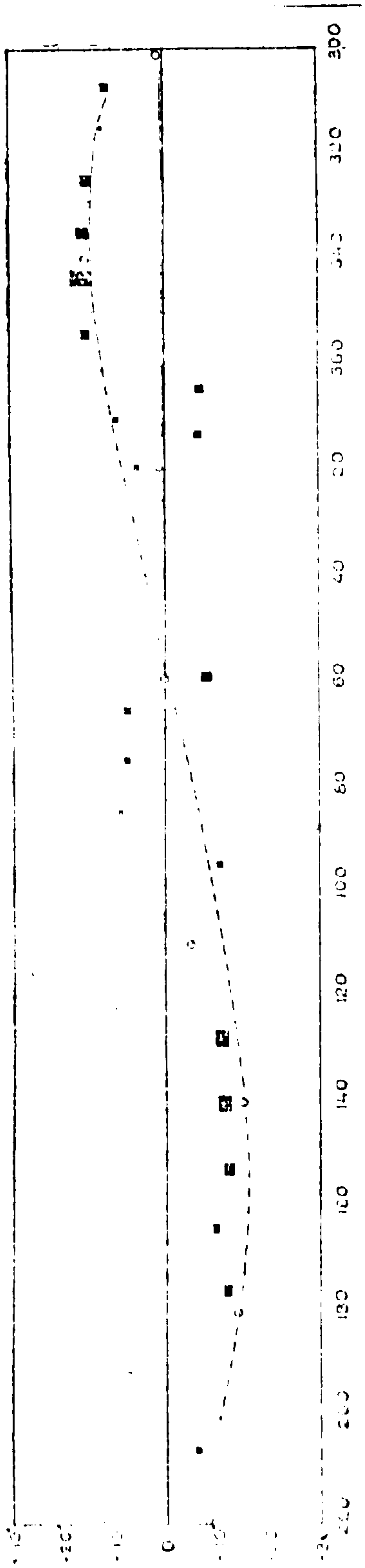

Figure 14

environs of the sun, should be responsible for this phenomenon. One can maintain that the observed dark nebulae are divided into two groups, which differ from each other in their location in the Galaxy. The first group is closely associated with the other members of the Galaxy, displaying a known concentration in the zone of the Galaxy. The second group of dark nebulae is not strictly planar, and its plane of symmetry is inclined towards the plane of symmetry of the Galaxy at an angle of 10.6°.

Consequently, the apparent distribution of dark nebulae of the second group coincides well with the distribution of stars in the local system, from which it follows that, first, it is impossible to consider the concentration of bright stars along Gould's pole a result of the comparatively great transparency of interstellar space along this zone, since it is precisely here that the dark nebulae are concentrated. Ye. K. Kharadze [30] and M. A. Vashakedze [20] of the Abastuman observatory, having studied the absorption of light in regions of the local system and those symmetrical to it, came to the same such conclusion. Second, it is not unfounded to assume that dark nebulae of the second group have a physical connection with the local system. The fact expressed above, which states that dark nebulae of the second group introduce a slight irregularity into the distribution of the total weight according to galactic longitude, expressed in the appearance of a second maximum in the direction of the anticenter of the Galaxy, agrees with these conclusions.

A similar picture, i.e. the division of the system of dark nebulae into two groups, can be perceived in K. Lundmark's map of dark nebulae [34].

Heretofore, we have studied all questions associated with the distribution of dark nebulae according to galactic coordinates with regard for the statistical weights we introduced, i.e. we tried to take into consideration the individuality of different directions in the heavens, in the sense of the quantitative differences in the interstellar matter in them. During the determination of the plane of symmetry, each area is assigned a weight P, which represents the sum of the weights p of the individual nebulae appearing in the given area.

However, as was indicated in chapter II, § 3, during the derivation of the formula $\overline{M} = k\overline{p}$, which is an indication of the proportionality of the average mass to the average statistical weight, the assumption was made that the average distance to the nebulae in the space under investigation is equal for all directions in the plane of the Galaxy. This means that we assumed the absence of sharp structural diversities in the spatial distribution of dark nebulae in a comparatively small cylinder with a base radius of 700parsecs. If one refrains /90 from rough statistical posing of the question, this assumption can be shown to be insufficiently exacting.

On the other hand, we determined the magnitude of $\Delta N(m)$ visually during the determination of p of individual dark nebulae, since the magnitudes of p are burdened with the errors inherent in visual methods.

In this connection, it proved advisable to repeat the calculations of the coordinates of the poles of the planes of symmetry of the dark nebulae without taking the statistical weights into account.

TABLE IV

№	α	δ	l	b	n
1	$16^h54^m.55$	$-25°.56$	310 [illegible]	$+2°.2$	22
2	17 24 37	−2[illegible]	320.0	+0.4	30
3	17 4[illegible]	−21.[illegible]	335.0	+0.6	31
4	18 12.07	−1[illegible]	[illegible]	0.9	27
5	18 [illegible]	−6 [illegible]	[illegible]	2.0	21
6	18 50.17	+1 [illegible]	[illegible]	1.4	6
7	19 08 8	+1[illegible]	10[illegible]	+0.8	13
8	19 25.55	+22.71	2[illegible]	+1.1	22
9	19 43.80	+30.52	[illegible]	+1.6	24
10	20 17.68	+38.81	[illegible]	+0.4	17
11	21 0.08	+4[illegible]	[illegible]	1.3	19
12	21 37 21	+53.[illegible]	[illegible]	0.8	28
13	22 27.40	+50.02	[illegible]	+1.3	8
14	0 [illegible]	+60.[illegible]2	8[illegible]	1.0	15
15	1 17.[illegible]	+60.00	94.[illegible]	0.8	14
16	2 0.60	+60.60	100.7	+0.4	5
17	4 1.17	+53.48	117.2	+2.1	6
18	[illegible]	+[illegible]	125.7	0.1	11
19	4 57.60	+35.02	1[illegible]9	1.8	10
20	5 23.72	+3[illegible]	145.0	0.8	7
21	5 58.00	+20.57	1[illegible]0	+0.8	3
22	6 14.71	+13.52	195.1	+0.9	14
23	6 35.45	+6.27	1[illegible]	1.0	11
24	7 0.0	[illegible]	[illegible]	+2.3	10
25	7 17.33	13 [illegible]	[illegible]	+1.5	9
26	7 26.00	21.00	204.3	0.5	9
27	16 27.35	31.04	[illegible]	+0.3	23
28	16 40.52	23.00	320.2	+11.1	41
29	17 48.60	33.0	[illegible]	5.6	15
30	17 11.67	17.01	351.[illegible]	+10.3	27
31	18 21.03	−25.71	35[illegible]	7.5	35
32	17 32.00	07.48	[illegible]2	+11.2	16
33	18 40.47	−17.3[illegible]	344.7	7.1	23
34	17 51.50	+1.18	35[illegible]2	+10.[illegible]	10
35	18 36.00	7.98	35[illegible]8	7.3	15
36	18 25.10	+13.40	10.2	+9.5	[illegible]
37	19 16.05	+0.18	[illegible]	7.9	8
38	19 04.00	+22.21	22.4	+5.2	8

/91

№	α	δ	$\bar{l}$	$\bar{b}$	n
39	19h 30m.00	+ 8.58	[illegible]	7.0	11
40	21 31.42	+43.30	57.[illegible]	[illegible]	[illegible]
41	20 59.51	+60.25	65.[illegible]	+ 8.0	15
42	22 3.40	+67.30	[illegible]	+ 9.[illegible]	5
43	23 51.44	+71.60	[illegible]	[illegible]	1[illegible]
44	1 43.00	+53.42	[illegible]	− 8.6	5
45	4 53.43	+53.81	122.3	− 8.8	7
46	3 45.50	+30.21	124.7	−19.1	[illegible]
47	7 20.16	− 5.03	100.7	+ 7.9	6
48	4 33.17	+26.56	140.7	−11.0	2[illegible]
49	5 4.50	+23.03	147.5	8.0	10
50	5 34.03	+ 8.15	163.[illegible]	10.3	1[illegible]
51	5 50.10	− 1.34	172.8	10.3	15
52	7 14.75	20.02	210.4	[illegible]	[illegible]
53	7 28.30	25.40	212.7	[illegible]	[illegible]

Table IV is similar to table III. The average coordinates for all 53 areas are given in it wit out consideration for the weights p. The first column contains the number of the area, and the second and third—the average values $\bar{\alpha}$ and $\bar{\delta}$, calculated according to the formulas:

$$\bar{\alpha} = \frac{\sum \alpha}{n}, \quad \bar{\delta} = \frac{\sum \delta}{n}.$$

The fourth and fifth columns give the average galactic coordinates $\bar{\ell}$ and $\bar{b}$, and, finally, the sixth gives the number of nebulae, n.

The positions of the poles of the planes of symmetry for each group of dark nebulae were calculated on the basis of this table. The principle of the division of the nebulae into two groups is the same as in the previous case, taking the statistical weight into account.

The determination of the positions of the poles of the planes of symmetry was carried out by Newcombe's method. For verification, calculations were conducted simultaneously in both equatorial and galactic coordinates. The obtained results are assembled in table V.

As is evident from table V, the coordinates of the poles of the planes of symmetry of the dark nebulae of each group turn out to be practically equal, both with and without the use of the statistical weights. Thus, all of the conclusions, made in the current paragraph in regard to the distribution of dark nebulae according to galactic coordinates, remain in effect.

TABLE V

	A	D	i	Ω
a 1. Вся система темных туманностей с применением статист. весов	186.5	+30.0	[illegible]	276.5
b без применения статист. весов	187.5	+20.0	[illegible]	277.5
c 2. I группа темных туманностей с примен. статист. весов	190.0	+28.0	0	280.0
без применения статист. весов	190.1	+26.2	0	280.1
d 3. II группа темных туманностей с применением статист. весов	178.0	+32.3	10.0	268.6
без применения статист. весов	177.0	+29.0	11.0	267.6

Key: a. Entire system of dark nebulae with the use of statistical weights
b. Without the use of statistical weights
c. Group I of dark nebulae with the use of statistical weights
d. Group II of dark nebulae with the use of statistical weights

§ 3. Distribution of Dark Nebulae according to Position Angles of Orientation /92

The tentative catalog of dark nebulae makes it possible to study the distribution of dark nebulae according to the magnitudes of the position angles of orientation φ. We were given the goal of establishing whether some primary direction exists in the apparent orientation of dark nebulae, or if they are oriented chaotically, not obeying any detectable general regularities. The actuality of this question is supported by the statements of Academician G. A. Shain [55] in connection with the study of the similar orientation (granted, of considerably different objects) of the light gas filaments in diffuse nebulae.

The construction of the function of distribution of dark nebulae according to φ, i.e. the function $f_1(\varphi)$, is interesting from the point of view of revealing the nature of the forces acting on dark clouds. We have already spoken of the possible nature of the forces, which can create the elongation of dark nebulae, in the third chapter, and emphasized that it is more likely that forces of different natures can act in different cases. But, even if it is difficult to precisely resolve the question of the nature of the forces, it is nevertheless interesting to at least elucidate the total average effect of these forces.

The distribution of dark nebulae according to angles of orientation was investigated by Ye. L. Ruskol [36] on a small amount of material (68 objects), taken from Barnard's catalog. Ruskol's results are in good agreement with ours, in spite of the low number of objects she investigated.

We should consider the following circumstance during the selection of material for the recording of the statistics of the angles of orientation φ. For such objects as elliptical dark filaments, and pear-shaped and triangular objects, one can draw the lines of the direction of elongation with great confidence. This is often possible for irregular dark nebulae as well. We tried to increase the number of nebulae involved in the statistical processing for greater reliability of the conclusions. Therefore, all of the nebulae displaying clear elongation (including irregular ones) comprised material for the study of the distribution of the angles.

However, the following reason can be put forth against the inclusion of irregular nebulae in the statistics. The elongation of an irregular nebula can be deceptive, being caused by the superimposition of one nebula onto another, which can lead to the fact that the effect of the total concentration of absorbing material toward the plane of the Galaxy is superimposed onto the effect of elongation of individual nebulae along the galactic plane.

Thus, the effect of the superimposition of nebulae on the nature of the distribution according to φ should be studied.

We will construct a graph of the distribution of nebulae according to galactic latitudes b for the determination of the degree of concentration of the dark nebulae towards the equator of the Galaxy. The graph is presented in figure 15.

The curve can be expressed approximately by the linear function:

$$n = n_0 - \gamma b, \qquad (8)$$

where n_0 is the number of nebulae at the galactic equator, and the magnitude of γ is the angular coefficient.

A change in density according to longitude ℓ is not significant for the given problem, and we therefore disregard it.

The probability that a nebula will have coordinates (ℓ, b), i.e. $P(\ell, b)$, is a magnitude proportional to the density at the point (ℓ, b), and is consequently expressed through: /93

$$P(\ell, b)\, d\ell\, db = k(n_0 - \gamma b)\, d\ell\, db,$$

with this,

$$P(l + \Delta l, b) = P(l, b)$$

Figure 15

We will assume that the nebula has a position ℓ,b (fig. 16).

The superimposition of one nebula onto another is realized when their coordinates (ℓ_1,b_1) and (ℓ_2,b_2) will differ by no more than the average diameter $\Delta\ell=\Delta b=\bar{d}$, i.e.

$$|l_1 - l_2| < \Delta l,$$
$$|b_1 - b_2| < \Delta b.$$

We will select four variants of the superimposition of nebulae. Two of them create an orientation parallel to the equator of the Galaxy, and two variants—perpendicular to it.

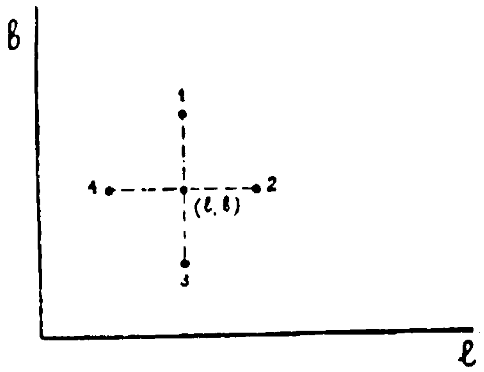

Figure 16

The problem consists of determining how much more likely the variants creating parallel orientation are, as compared with the variants creating perpendicular orientation. It is simple to solve.

The probability of realization of the first variant (see fig. 16) is equal to:

$$P_1 = P(l, b)\,P(l, b + \Delta b).$$

Similarly, we write for the remaining variants:

$$P_2 = P(l, b)\,P(l + \Delta l, b),$$
$$P_3 = P(l, b)\,P(l, b - \Delta b),$$
$$P_4 = P(l, b)\,P(l - \Delta l, b).$$

The posed problem is solved by the relationship:

$$\frac{P_1 + P_3}{P_2 + P_4} = \frac{P(l, b + \Delta b) + P(l, b - \Delta b)}{2P(l, b)}.$$

In virtue of (8), <u>i.e.</u> the linearity of the function $P(\ell, b)$, the numerator of the relationship is equal to $2P(\ell, b)$, <u>i.e.</u> it happens that /94

$$\frac{P_1 + P_3}{P_2 + P_4} = 1.$$

Thus, all orientations created by the superimpositions are equally probable.

In that case when a nebula lies on the galactic equator, we obtain the formula:

$$\frac{P_1 + P_3}{P_2 + P_4} = 1 - \frac{\Delta b}{20} = 0.92,$$

with the assumption that the average diameter of the nebula is equal to 1.6°.

Thus, the effect of superimposition of nebulae can not substantially change the nature of the distribution of the nebulae according to φ.

However, for greater exactness, we selected only elliptical nebulae and dark filaments in the catalong, in regard to which there can be no doubt as to the reality of their shape. The list of these nebulae is given in table VI.

The statistics for these nebulae are recorded separately, and the cross-hatched portions in diagrams 17 and 19 (which are basically constructed for regular and irregular nebulae taken together) correspond to them. As we see, the nature of the distribution of both regular and irregular nebulae is almost identical. /95

TABLE VI

№	φ	№	φ	№	φ	№	φ	№	φ	№	φ
15	19°	228	50	318	[illegible]	430	5°	[illegible]	9°	677	23°
19	31	220	00	322	50	444	17	[illegible]	9	680	08
23	40	230	75	325	10	447	3[illegible]	556	4[illegible]	682	36
30	23	232	12	334	22	455	7	[illegible]	[illegible]	685	20
32	0	234	39	336	31	459	2	560	40	687	31
45	13	239	70	339	31	460	7[illegible]	561	47	688	25
50	29	241	49	340	[illegible]	477	50	56[illegible]	10	689	11
58	20	244	89	343	51	480	24	567	25	690	10
59	54	249	47	345	16	482	15	[illegible]	[illegible]	692	42
77	15	251	9	347	37	486	[illegible]	[illegible]	14	697	8
[illegible]	21	250	19	35[illegible]	[illegible]	[illegible]	[illegible]	57[illegible]	[illegible]	[illegible]	23
87	[illegible]	256	[illegible]	35[illegible]	10	491	[illegible]	[illegible]	2[illegible]	706	72
102	39	2[illegible]0	30	[illegible]	6[illegible]	495	[illegible]	57[illegible]	[illegible]	709	31
114	10	264	[illegible]3	[illegible]	4[illegible]	499	0	[illegible]	11	712	05
118	30	26[illegible]	[illegible]	305	17	500	7[illegible]	[illegible]	[illegible]	71[illegible]	2
128	[illegible]	270	10	367	[illegible]	502	6	56[illegible]	[illegible]	718	26
133	[illegible]4	271	[illegible]	370	[illegible]	504	[illegible]	582	5	722	2
138	40	273	[illegible]	370	15	505	7	5[illegible]	3	723	5
142	84	274	2	374	5	507	[illegible]	5[illegible]	1[illegible]	724	12
149	70	275	2[illegible]	387	27	509	0	[illegible]	2	727	51
150	28	276	18	389	5	[illegible]	[illegible]	[illegible]	25	73[illegible]	04
163	40	277	14	393	7	513	2		10	73[illegible]	03
183	67	278	51	39[illegible]	71	516			17	737	47
184	02	[illegible]	[illegible]	[illegible]	0	518	[illegible]	[illegible]	[illegible]2	740	[illegible]
188	[illegible]	283	[illegible]	[illegible]	4[illegible]	521	2[illegible]	[illegible]	[illegible]	747	[illegible]
190	13	284	[illegible]	400	3	537	[illegible]	[illegible]	10	749	[illegible]
191	17	285	[illegible]	407	2[illegible]	536			2[illegible]	757	[illegible]
194	3	28[illegible]	1[illegible]	410	52	539	7	[illegible]	6	765	[illegible]
195	4[illegible]	[illegible]	0	415	42	540	10	[illegible]		70[illegible]	[illegible]
196	33	29[illegible]	8[illegible]	4[illegible]	30	541	[illegible]	[illegible]	33	775	8[illegible]
200	13	295	87	422	[illegible]	542	1[illegible]	[illegible]	0	77[illegible]	[illegible]
203	10	297	[illegible]	[illegible]	40	543	[illegible]	[illegible]	2[illegible]	78[illegible]	[illegible]
206	25	301	1	427	[illegible]	545	17	[illegible]	[illegible]	787	7
214	20	306	20	42[illegible]	7	547	10	[illegible]	[illegible]1	79[illegible]	42
220	72	307	2[illegible]	430	33	553	7[illegible]	[illegible]	8	797	15
226	1	315	10	431	88						

A diagram, which indicates the number of dark nebulae which have different apparent angles of orientation from 0° to 90°, is presented in figure 17. As is evident from the diagram, the majority of dark nebulae is oriented in a direction lying at the galactic equator in the picture plane. But more interesting is the fact that the minimum of the number of dark nebulae does not coincide with the value for $\varphi = 90°$, but lies near $\varphi = 65°$. In Ruskol's analogous diagram, the minimum also lies near $\varphi = 65°$.

As has become known from the newest investigations of Academician G. A. Shain, the presence of magnetic fields in the Galaxy may be responsible for the primary orientation of dark nebulae parallel to the equator of the Galaxy.

Dark nebulae can be oriented by their elongations differently in space, and the question of what kind of orientation this is

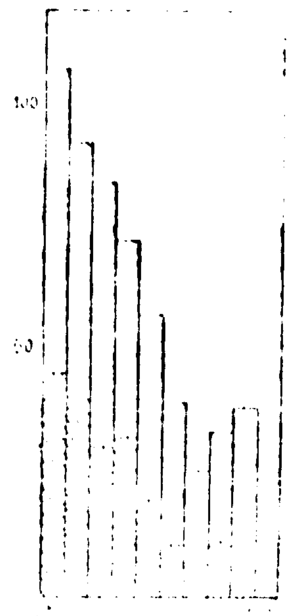

Figure 17

in respect to the plane of the Galaxy is of interest. We will designate the least angle between the direction of elongation and the plane of the Galaxy with the letter ψ (figure 18), and the angle formed by this same direction with the picture plane—with the letter θ. For the change from $f_1(\varphi)$ to $f_2(\psi)$—the functions of distribution according to the true angles of inclination of the elongations of the dark nebulae to the plane /96
of the Galaxy,—we will utilize the method used by Ruskol, which is more valid for our case. (The assumption $f_3(\theta)$=const, which Ruskol made use of, requires that the statistics be recorded throughout the range of the galactic zone—a condition which it is significantly better to observe in our investigation).

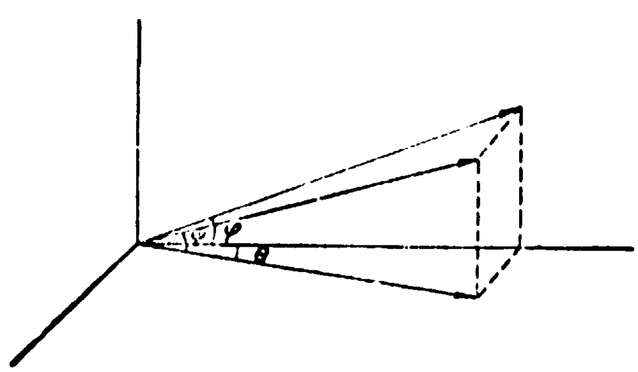

Figure 18

The task of studying the law of spatial orientation of dark nebulae amounts to the following: we have three random variables φ, ψ, and θ, which are interrelated by the relationship (see fig. 18):

$$\operatorname{tg}\psi = \operatorname{tg}\varphi \cos\theta \tag{9}$$

and we are required to find the distribution function $f_2(\psi)$, when the distribution functions $f_1(\varphi)$ and $f_3(\theta)$ are known. The function $f_1(\varphi)$ is known from observation, and one can make some assumption or another concerning the function $f_3(\theta)$, for example:

$$f_3(\theta) = \text{const.} \tag{10}$$

As is common knowledge from the theory of probability, this task amounts to the solution of an integral equation of the type:

$$f_2(\psi)\,d\psi = \frac{\text{const}\,d\psi}{\cos^2\psi}\int_{\infty}^{+\infty}\frac{f_1(\varphi)\,d\operatorname{tg}\varphi}{(1+\operatorname{tg}^2\varphi)\sqrt{\operatorname{tg}^2\varphi-\operatorname{tg}^2\psi}} \tag{11}$$

Here, one can also use the graphic method, which is completely suitable for our case, for the solution of this equation. It consists of the determination of the probabilities for each value of ψ according to the values of φ from 0° to 90°, by means of measuring the relationship of the areas on the map included between the straight lines of φ and the family of curves $\operatorname{tg}\psi=\operatorname{tg}\varphi\cos\theta$. Thus, a table is compiled, the use of which permits the switch from the function $f_1(\varphi)$ to $f_2(\psi)$. After conversion of the function, $f_2(\psi)$ took on a new form, presented in figure 19.

As is evident, the elongations of dark nebulae are primarily oriented parallel to the plane of the Galaxy.

§ 4. Distribution of Dark Nebulae according to Surface Areas /97

As has already been noted, the apparent surface area is the solid angle at which the greatest cross-section of a dark cloud with the picture plane is visible. It is in simple dependence on the true value of this cross-section, expressed by means of the distance r to the dark cloud:

$$\Sigma = \omega r^2. \tag{12}$$

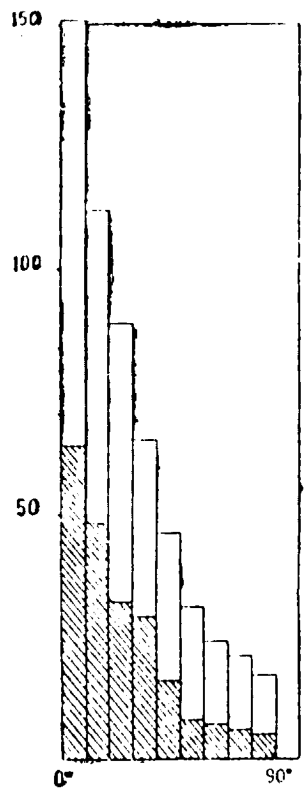

Figure 19

The sum of all σ is 1900 square degrees, i.e. all of the dark nebulae in the heavens cover an area equal to 1900 square degrees, which is roughly 40-50% of the surface of the Milky Way. According to Becker [6], it is 30-40%, which seems somewhat understated to us.

The distribution of dark nebulae according to apparent surface areas is presented in table VII. Given in the table are the values of the number of dark nebulae n (frequency) for each σ, which vary by 0.5 square degrees. It is evident from the table that dark nebulae of small dimensions are encountered most often, and their number decreases with an increase in σ. We could not determine the apparent area for thos dark nebulae with σ of less than 0.1 square degrees. Therefore, the table begins from σ=0.1 square degrees. We did not include values of σ exceeding 15 square degrees in the table, since such cases are very few.

For the totality of our statistical material, we calculated the values of a number of statistical characteristics. The /98 arithmetic mean turned out to be equal to

$$\bar{\sigma} = 2.1 \text{ square degrees}$$

TABLE VII

№№	σ	n	№	σ	n
1	0.25	252	16	7.75	4
2	0.75	130	17	8.25	5
3	1.25	92	18	8.75	1
4	1.75	51	19	9.25	0
5	2.25	60	20	9.75	1
6	2.75	27	21	10.25	[illegible]
7	3.25	27	22	10.75	2
8	3.75	31	23	11.25	4
9	4.25	18	24	11.75	2
10	[illegible]	14	25	12.25	[illegible]
11	5.25	17	26	12.75	1
12	5.75	19	27	13.25	1
13	6.25	[illegible]	28	13.75	2
14	6.75	5	29	14.25	1
15	7.25	10	30	14.75	1

But dark nebulae of such an apparent area are not encountered more often than others, since the coefficient of asymmetry has a value greater than zero:

$$S_{\lambda} = 2.21,$$

and, thus, an extreme left asymmetry is present.

For the mean square deviation of α, we obtained

$$\alpha = 2.7 \text{ square degrees},$$

from which it follows that the σ for 89% of the examined dark nebulae falls within the interval $0.1 < \sigma < 8.0$ square degrees.

According to Kreiken, the average distance to dark nebulae characterized by high levels of absorption is equal to 150 parsecs. Then, since the average apparent radius is equal to 0.81°, according to our data, the average true radius of dark nebulae t ned out to be

$$\bar{R} = 2.1 \text{ parsecs}.$$

During the construction of the curve of distribution of dark nebulae according to σ, we should consider the circumstance that we have no data within the interval $0<\sigma<0.1$ square degrees. This was caused by the fact that it was impossible to record dark nebulae with σ less than 0.1 square degree in our material. However, this interval is significant, since it can fill the remaining part, and this provides us with the opportunity to discuss questions which concern dark nebulae with all possible values of σ from 0 to ∞.

Thus, extrapolation of the distribution curve towards small σ would expand the space inside of which the study of dark nebulae would be possible.

We will explain this question in detail. We cannot record those dark nebulae for which $0<\sigma\leq0.1$ square degrees. This means that we do not note those nebulae, the true area Σ of which is less than the limit Σ_{min}, which creates the apparent $\sigma=\Sigma_{min}/r^2$ ≤0.1 square degrees. On the other hand, and this is more important, we also do not note a dark nebula which is farther than r_{max} from us, i.e. at a distance at which the nebula creates an apparent $\sigma<\Sigma/r^2_{max}\leq0.1$ square degrees. Thus, our distribution according to σ furnishes us information about those dark nebulae which are located inside a sphere, the radius of which can be determined in the following manner. The average true radius $\bar{R}$ is equal to 2.3 parsecs, according to P. P. Parenago. Such a nebula creates an apparent area $\sigma=0.1$ at a distance of 700 parsecs. Thus, our curve of distribution of $f(\sigma)$ characterizes nebulae withh are no more than 700 parsecs away from us. /99

When we conduct extrapolation of the curve towards small σ, we are assuming that nebulae with very small σ, i.e. farther than 700 parsecs away from us, will become visible for us. In other words, we thereby expand the space being studied. The further the extrapolation goes in the direction of small σ, the greater the radius of the space being studied will be. Nebulae having $\sigma=0.01$ square degrees will be an average of 200 parsecs away from us, and nebulae with $\sigma=0.001$ square degress—7000 parsecs.

Thus, extrapolation of the curve of $f(\sigma)$ is significant, and therefore requires a more careful approach to it.

We will pose the question: what form should the curve of $f(\sigma)$ have in the interval $0<\sigma\leq0.1$ square degrees? Two variants are possible in all.

1. The curve continues to rise, approaching the y-axis asymptotically or crossing it. 2. The curve reaches a maximum somewhere near the point $\sigma=0$. We should elucidate which of these two extreme variants is closer to the truth.

We have already indicated above that we were not pursuing the goal of detecting, and especially studying, globules, and, in addition, we did not include most globules, located against a background of bright diffuse nebulae, in the catalog. The apparent surface area of the globules also falls just in the interval $0<\sigma\leq 0.1$ square degrees. Individual filaments should also be added to this interval. Thus, if we would bear in mind the huge number of globules and dark filaments, the curve of $f(\sigma)$ would rise quite high in the interval $0<\sigma\leq 0.1$.

The revelation of the nature of the function $f(\sigma)$ is possible from the following general considerations. We will take some physical model of the system of dark nebulae. We will assume that all dark nebulae have equal true dimensions, and that they are distributed uniformly in space, i.e.

$$\Sigma = \text{const}, \ D(r) = \text{const}.$$

In such a case, as we will see subsequently, the distribution function $f(\sigma)$ will have the form:

$$f(\sigma) = \frac{\text{const}}{\sigma^{5/2}}. \tag{13}$$

Thus, this assumption about the nature of $D(r)$ and Σ gives the function $f(\sigma)$, which increases quickly (more quickly than observations permit) for small σ, and approaches the y-axis asymptotically.

One can make still more general assumptions. Assuming D(r)=const and taking the form: /100

$$\varphi(\Sigma)\,d\Sigma = \frac{4h^3}{\sqrt{\pi}}\,\Sigma^2 e^{-h^2\Sigma^2}\,d\Sigma,$$

which is similar to the distribution of the coefficients of the random variables distributed normally, for the distribution of nebulae according to the true areas Σ, i.e. for $\varphi(\Sigma)$, $f(\sigma)$ should take the following form (proof will be given below):

$$f(\sigma) = \frac{\omega D_0 \Gamma\left(\frac{9}{4}\right)}{\sqrt{\pi}\, h^{3/2}}\,\sigma^{[illegible]}. \tag{14}$$

Thus, in this case as well, $f(\sigma)$ turns out to be descending throughout the interval $0<\sigma<\infty$.

All of the considerations and examples set forth above speak in favor of the first variant, and, therefore, the assumption that the curve of $f(\sigma)$ rises in the interval $0<\sigma\leq 0.1$ seems more correct to us. It should be emphasized that formulas (13) and (14), derived above, do not have a physical meaning at the point $\sigma=0$. We should exclude this point from the examination, since the very concept "nebula with zero area" is devoid of physical meaning, and the number of nebulae is finite for all of the remaining finite values of σ. Reconciliation with the drawback that at $\sigma=0$, $f(\sigma)=\infty$ is unavoidable. We seldom encounter similar inevitabilities in astronomy. We would recall, for example, Seeliger's function of stellar density, $D(r)=\gamma r^{-\lambda}$ or $\lg D(r)=a-b(\lg r-c)^2$, which also has no meaning at the point $r=0$.

For greater clarity, we will examine the expression of our distribution, extrapolated according to the second variant, as a limited example. Such a distribution, when the curve begins at the origin of the coordinates, rises to a maximum, and then falls, is very often successfully expressed by means of the function:

$$f(\sigma)\,d\sigma = \frac{4h^{2n+1}}{\sqrt{\pi}}\sigma^{2n}e^{-h^2\sigma^2}\,d\sigma. \qquad (15)$$

This function reaches a maximum at the point:

$$\sigma = \frac{\sqrt{n}}{h}. \qquad (16)$$

It is easy to see that function (15) can not depict the observed distribution. Actually, our observed curve of $f(\sigma)$, if it is expressed by function (15), should reach a maximum somewhere in the interval $0<\sigma\leq 0.1$. Then, on the basis of equation (16), one can conclude that

$$h \geqslant 10.$$

And with such a values of $h>10$, function (15) has a value on the order of 10^{-30} at the point $\sigma=1$. This means that we should not see a single nebula with a σ greater than one square degree, which is quite impossible to reconcile with the observed fact. Thus, it is quite impossible to express the observed distribution by a function of the type (15).

Points which indicate the frequencies of nebulae for each σ, which change by 0.1 square degrees, are drawn in figure 20. The position of the points can be depicted with an equilateral hyperbola, the parameter C^2 of which can be determined as the average of the product $n\sigma$; thus, our distribution can be evened out by the expression: /101

$$f(\sigma) = \frac{73.00}{2\sigma}. \tag{17}$$

This curve is depicted in figure 20 (solid curve). It is evident from the figure that function (17) evens out the distribution according to σ sufficiently well.

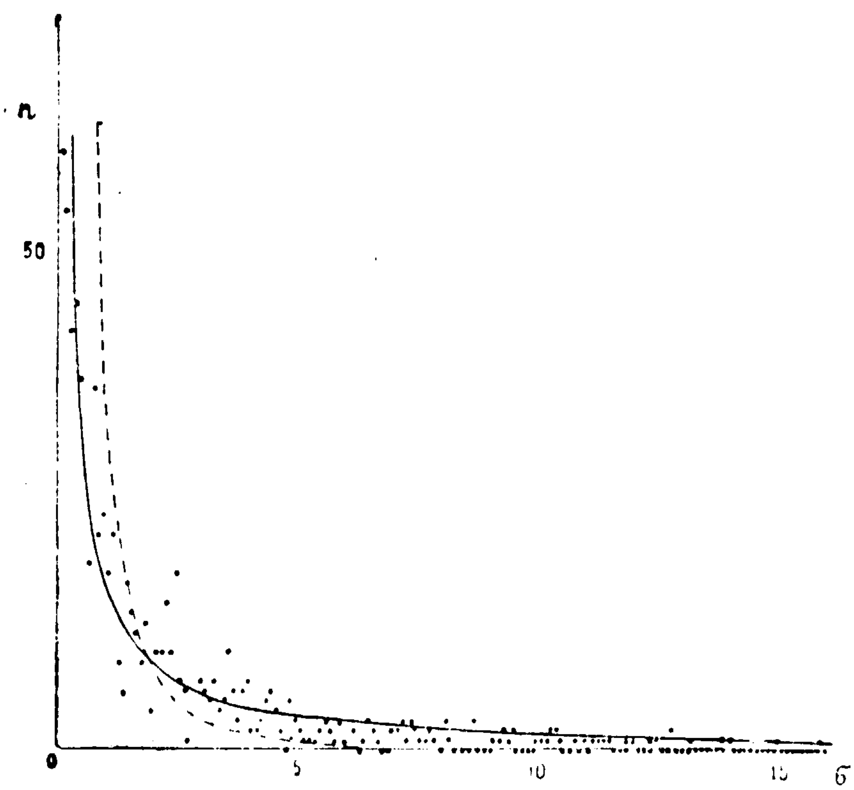

Figure 20

The form of the function $f(\sigma)$ depends on the analytical expressions of the following two functions: the function of spatial density of dark nebulae $D(r)$, and the function of distribution of dark nebulae according to true cross-sections Σ, i.e. $\varphi(\Sigma)$. As concerns these functions, we will first make a most trivial assumption

$$D(r) = \text{const}, \ \Sigma = \text{const}, \tag{18}$$

i.e. we will assume that the dark nebulae are distributed uniformly in space and have equal dimensions. It is easy to see that the distribution function will have the form of (13) in such a case.

Actually, σ will depend on the distance r in this case. We will imagine a cone with a solid angle ω, the axis of which is directed along the line of sight (fig. 21). The number of dark nebulae in the elementary volume will be:

$$\omega r^2 D(r)\,dr. \tag{19}$$

It is also the number of dark nebulae which have an apparent surface area $\sigma=\Sigma/r^2$. /102

Substituting

$$r^2=\Sigma\sigma^{-1}, \quad dr=-\frac{1}{2}\Sigma^{\frac{1}{2}}\sigma^{-\frac{3}{2}}d\sigma$$

into (19), we will obtain expression (13) for the function $f(\sigma)$.

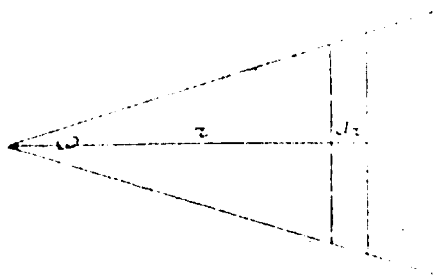

Figure 21

Function (13) is depicted in figure 20 (dotted line), and clearly does not coincide with form (17) of the function $f(\sigma)$. The reason for this noncoincidence evidently lies in the incorrectness of assumption (18).

We will pose ourselves a problem of a more general nature. We are interested in the analytical expressions of the following functions: $D(r)$, $\varphi(\Sigma)$, and $f(\sigma)$, one of which, namely $f(\sigma)$, is known from observations. One can interrelate these functions using the integral equation of stellar statistics. Actually, for our case, Schwarzchild's first equation

$$A(\sigma)=\omega\int_0^\infty r^2 D(r)\varphi(\Sigma)\frac{d\Sigma}{d\sigma}dr.$$

will have the form:

$$f(\sigma)=\omega\int_0^{\infty} r^4 D(r)\,\varphi(r^2\sigma)\,dr, \tag{20}$$

taking (12) into account. By making some sort of assumption concerning D(r), one can determine $\varphi(\Sigma)$ from this equation, considering the left side of the equation known.

At first, we will limit ourselves to that portion of the curve of $f(\sigma)$ which is provided by direct observation, <u>i.e.</u> we will make no assumptions whatsoever concerning the nature of the extrapolation of the curve in the interval $0<\sigma<0.1$. Consequently, we have:

$$f(\sigma) = \frac{C^2}{2\sigma},$$

where

$$0.1\leq\sigma\leq 15.$$

This means that we are studying the space inside of a cylinder with a base radius H=700 parsecs. In this case, we should integrate from zero to H, according to r, and, in addition, one can quite freely take the density of the nebulae as equal, i.e. $D(r)=D_0$=const, in such a small space. After what has been said, equation (20) will take the form: /103

$$\frac{C^2}{2\sigma}=\omega D_0\int_0^{H} r^4\varphi(\sigma r^2)\,dr. \tag{21}$$

We will determine the function $\varphi(\Sigma)$ from this equation.

After designating $\sigma r^2=x$, equation (21) is rewritten as:

$$\sigma^{3/2}=\frac{\omega D_0}{C^2}\int_0^{\sigma H^2} x^{3/2}\varphi(x)\,dx.$$

We will introduce the variable

$$\sigma H^2 = t.$$

Then we will obtain:

$$t^{3/2} = \frac{\omega D_0 H^3}{C^2} \int_0^t s^{1/2} \varphi(s)\, ds.$$

We will take the derivative according to t of both sides of the last equation. We obtain:

$$\frac{3}{2} t^{1/2} = \frac{\omega D_0 H^3}{C^2} t^{1/2} \varphi(t),$$

from which we determine the function

$$\varphi(t) = \frac{3C^2}{2\omega D_0 H^3} \frac{1}{t}$$

or

$$\varphi(\Sigma) = \frac{\Sigma_0'}{\Sigma}, \qquad (22)$$

where

$$\Sigma_0' = \frac{3C^2}{2\omega D_0 H^3}.$$

Thus, the function of distribution of dark nebulae according to the true areas Σ has the form of an equilateral hyperbola. This function has one drawback, which becomes noticeable at the very first glance: the point $\Sigma=0$ is its singular point. Therefore, the total number of nebulae—the integral of function (22) from zero to infinity—is infinite, and, in addition, function (22) does not have an average value. However, all of these drawbacks become superfluous if we exclude the point $\Sigma=0$ and agree to determine the lower limit of the area of the nebulae Σ_{min} according to physical considerations. We will examine function (22) in the limited interval (Σ_{min}, Σ_{max}), and then the total number of nebulae turns out to be finite, and the average value is also determined.

When we speak of the suitability of expression (22) for the representation of the distribution function, we should emphasize one important fact. Expression (22), as a distribution function, has a completely real and definite meaning, since it is type XI of Pearson's distribution curves, i.e. a definite stochastic scheme lies at the basis of such a distribution.

We have already said that extrapolation of the curve of /104
f(σ) expands the space being studied. We will try to study

the nature of the functions D(r), $\varphi(\Sigma)$, and $f(\sigma)$ in the space from 0 to ∞, as is done during the examination of the equations of stellar statistics relative to stellar functions.

We will first prove that, with the assumption concerning the functions D(r) and $\varphi(\Sigma)$:

$$D(r) = const \quad \text{и} \quad \varphi(\Sigma)\,d\Sigma = \frac{4h^{3/2}}{\sqrt{\pi}}\Sigma^2 e^{-h\Sigma^2}\,d\Sigma, \tag{23}$$

$f(\sigma)$ should have a form which does not coincide with the forms of the function $f(\sigma)$ obtained from observations. With assumption (23), Schwarzchild's equation will take the form:

$$f(\sigma) = \omega\frac{4h^{3/2}D_0}{\sqrt{\pi}}\sigma^2\int_0^\infty r^8 e^{-h\sigma^2 r^4}\,dr.$$

After the substitution: $r\sqrt{h}\sqrt{\sigma} = t$, we obtain:

$$f(\sigma) = \frac{4\omega D_0}{\sqrt{\pi}\,h^{3/4}}\frac{1}{\sigma^{5/2}}\int_0^\infty t^8 e^{-t^4}\,dt = \frac{\omega D_0\Gamma\left(\frac{9}{4}\right)}{\sqrt{\pi}\,h^{3/4}}\frac{1}{\sigma^{5/2}},$$

<u>i.e.</u>

$$f(\sigma) = \frac{C'}{\sigma^{5/2}},$$

where

$$C' = \frac{\omega D_0\Gamma\left(\frac{9}{4}\right)}{\sqrt{\pi}\,h^{3/4}}$$

is a constant magnitude.

By having one equation (20) with two unknown functions, D(r) and $\varphi(\Sigma)$, it is impossible to unequivocally determine both functions; however, one can nevertheless obtain some conclusions of a general nature.

Actually, the equation

$$f(\sigma) = \omega\int_0^\infty r^4 D(r)\,\varphi(\sigma r^2)\,dr$$

already indicates that, with the assumption

$$\varphi(\Sigma) = const,$$

it cannot give a function $f(\sigma)$ which is similar to the observed one, since we would then obtain

$$f(\sigma) = const \int_0^\infty r^4 D(r)\,dr = const.$$

It also arises from the 1ast integral that D(r) cannot be an ascending function throughout the interval $(0,\infty)$, which is natural from physical considerations.

One can show something similar in regard to the function D(r). After the substitution $\sigma r^2=u$, the assumption D(r)=const gives equation (20) the following form:

$$f(\sigma) = const\,\sigma^{-5/2}\int_0^\infty u^{3/2}\varphi(u)\,du = const\,\sigma^{-5/2}.$$

The function $\varphi(\Sigma)$ cannot be an ascending function throughout the interval $(0,\infty)$. /105

Thus, when we study a large amount of space, it is then impossible to consider the function of density D(r) constant. One could also arrive at the conclusion from physical considerations.

For the spatial density of dark nebulae, P. P. Parenago assumed as valid the e·ponential law:

$$D(r) = D_0 e^{-\beta r}, \qquad (24)$$

which, as we will see later, does not contradict the observed data.

We will take forms (17) and (24), respectively, for the functions $f(\sigma)$ and D(r), and determine the function $\varphi(\Sigma)$ from equation (20).

We will have:

$$\frac{C^2}{2\sigma} = \omega D_0 \int_0^\infty r^4 e^{-\beta r}\varphi(r^2\sigma)\,dr$$

We will introduce the designations

$$r^2\sigma = u^2, \qquad \frac{\sin\beta}{\beta} = \gamma;$$

then

$$\frac{C^2}{2\sigma} = \omega D_0 \sigma^{-5/2}\int_0^\infty u^4 e^{-\gamma u}\varphi(u^2)\,du. \qquad (25)$$

We will designate:

$$\sqrt{\frac{\Sigma}{\sigma_0}} = u, \quad u^2\varphi(u^2) = S(u^2), \quad \frac{C^2\gamma^3}{2D_0\,\omega} = A_0.$$

After this, (25) will take the form:

$$\int_0^\infty u^2 S(u^2) e^{-\alpha u}\,du = \frac{A_0}{\alpha^3}. \tag{26}$$

It is easy to see that equation (26) is satisfactory with

$$S(u^2) = \frac{1}{2}A_0.$$

Thus,

$$u^2\varphi(u^2) = A_0,$$

from which it follows that

$$\varphi(\Sigma) = \frac{\Sigma_0}{\Sigma},$$

where

$$\Sigma_0 = \frac{C^2\gamma^3}{4\omega D_0}.$$

Thus, we obtained the last expression for the function of distribution of dark nebulae according to the true surface areas Σ, i.e. for $\varphi(\Sigma)$; with this, we proceeded from form (17) of the function $f(\sigma)$, obtained according to the given observations, and from form (24) for the function $D(r)$, proposed by P. P. Parenago and the most well-founded of the expressions of spatial density of dark nebulae known to us.

§ 5. Distribution of Dark Nebulae according to Statistical Weights /106

During the definition of the concept "statistical weights of dark nebulae" in the second chapter of the present investigation, we indicated that the weight p is associated with the mass of the nebulae by the equality

$$M = kpr^2.$$

It is evident that the function of distribution of dark nebulae according to the statistical weights p is of definite interest.

TABLE VIII

№№	p	n	n'	N	N'	Δ	№№	p	n	n'	N	N'	Δ
1	0.25	107	125	107	125	18	[illegible]	[illegible]	13	13	607	612	5
2	0.75	84	66	191	191	[illegible]	[illegible]	[illegible]	13	12	620	625	4
3	1.25	40	52	231	240	15	[illegible]	10.25	14	11	634	635	1
4	1.75	41	43	272	289	17	22	[illegible]	14	11	648	646	2
5	2.25	43	37	315	[illegible]	11	[illegible]	[illegible]	[illegible]	10	657	656	1
6	2.75	40	33	355	359	4	[illegible]	[illegible]	10	9	[illegible]	665	2
7	3.25	31	29	366	388	2	25	[illegible]	[illegible]	9	675	674	1
8	3.75	31	27	417	415	2	[illegible]	[illegible]	[illegible]	8	683	682	1
9	4.25	30	24	447	439	[illegible]	27	[illegible]	[illegible]	8	[illegible]	690	0
10	4.75	31	23	478	462	[illegible]	[illegible]	[illegible]	7	7	697	697	0
11	5.25	20	21	498	483	[illegible]	[illegible]	14.25	4	6	701	703	2
12	5.75	20	20	518	503	15	[illegible]	[illegible]	4	6	705	709	4
13	6.25	18	19	536	522	[illegible]	[illegible]	[illegible]	7	5	712	714	2
14	6.75	18	18	554	540	14	[illegible]	[illegible]	[illegible]	5	718	719	1
15	7.25	14	16	[illegible]	560	12	[illegible]	[illegible]	[illegible]	4	721	723	2
16	7.75	14	15	582	571	11	[illegible]	[illegible]	[illegible]	3	724	726	2
17	8.25	[illegible]	15	588	586	2	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]	0
18	8.75	[illegible]	14	[illegible]	600	0	[illegible]	[illegible]	3	1	[illegible]	729	2

Table VIII represents the distribution of dark nebulae according to the statistical weights p. Given in the first column are the values of p, which change by magnitudes of 0.5 from 0.25 to 17.75, and in the second column—the corresponding numbers of the dark nebulae n. Dark nebulae with weights p greater than 18.0 are not included in the table, since such nebulae are encountered extremely rarely. As is evident from the table, dark nebulae with small values of p are encountered most frequently, and their number quickly decreases with an increase in p.

The method of moments [57] was utilized to find the mathematical expression of the function of distribution of dark nebulae according to the weights p, i.e. F(p). The central moments of our distribution have the values:

$$\mu_2=19.822, \qquad \mu_3=94.921, \qquad \mu_4=1271.282.$$

For Pearson's criterion, we obtained the value:

$$\varkappa = \frac{\beta_1(\beta_2+3)^2}{4(4\beta_2-3\beta_1)(2\beta_2-3\beta_1-6)} = [illegible]0.29,$$

where

$$\beta_1 = \frac{\mu_3^2}{\mu_2^3} = 1.1[illegible] \qquad \beta_2 = \frac{\mu_4}{\mu_2^2} = [illegible]$$

Thus, of the thirteen types of Pearson's curves, type I proved appropriate for our case. However, since we have the expression: /107

$$5\beta_2 - 6\beta_1 - 9 = 0.238,$$

which can be considered equal to zero, the given distribution can be evened out by Pearson's curve type XII, which is a special case of type I. Thus, for F(p), we obtain the expression:

$$F(p) = y_0 \left(\frac{a + p}{b - p} \right)^{m} \qquad (27)$$

The parameters of the curve are determined according to the formulas [59]:

$$a = \sqrt{\mu_2}\,(\sqrt{3+\beta_1} + \sqrt{\beta_1}) = [illegible]$$

$$b = \sqrt{\mu_2}\,(\sqrt{3+\beta_1} - \sqrt{\beta_1}) = 4.3$$

$$m = \sqrt{\frac{\beta_1}{3+\beta_1}} = 0.[illegible]27$$

$$y_0 = \frac{N}{2\sqrt{\mu_2}\,(3 + \beta_1)\ [illegible]}\ [illegible]$$

m has a minus sign, since $\mu_3 > 0$. Function (27) extends from -a to b, and, in order to depict our distribution, we should move the origin of the coordinates by a magnitude d along the x-axis. Consequently, we obtain for the function F(p), making $m = 0.527 \approx 0.5$:

$$F(p) = y_0 \sqrt{\frac{\alpha - p}{p}}, \qquad (28)$$

where

$$\alpha = a + b.$$

One can see how well expression (28) evens out the frequencies of our distribution by calculating Kolmogorov-Smirnov's criterion of agreement. In table VIII, the third column gives the values of the frequencies n', calculated according to formula (28). The value

$$\lambda = 0.66$$

was obtained for Kolmogorov-Smirnov's criterion of agreement, which indicates that expression (28) depicts the function of distribution of dark nebulae according to the statistical weights p sufficiently well. Figure 22 also convinces us of this, in which the points are dr wn according to table VIII, and the curve is drawn according to expression (28).

Thus, the curve of F(p) changes in the interval $0.1 \leq p \leq 18$, and characterizes the distribution of dark nebulae located closer than 700 parsecs. We can construct a function of distribution according to mass S(M) for these nebulae. The functions F(p) and S(M) are associated by Schwarzchild's equation

$$p_0 \sqrt{\frac{\alpha - p}{p}} = \omega k D_0 \int_0^H r^4 S(k p r^2)\, dr, \qquad (29)$$

where the assumption is made that the density of the nebulae is constant in the space being studied, <u>i.e.</u>

$$D(r) = D_0 = \text{const},$$

and form (28) is taken for the function F(p).

We will designate /108

$$\frac{p_0}{\omega k D_0} = a, \qquad k p r^2 = x;$$

then, equation (29) is rewritten as:

$$2 k^{-5/2} a p^2 \sqrt{\alpha - p} = \int_0^{kH^2 p} x^{3/2} S(x)\, dx,$$

which, after the substitution

$$kH^2 p = t, \qquad \alpha k H^2 = b,$$

takes the form:

$$\frac{2a}{H^5} t^2 \sqrt{b - t} = \int_0^t x^{3/2} S(x)\, dx.$$

Taking the derivative according to t of both sides of the last equation, we will obtain:

$$S(t) = \frac{a}{H^5} \cdot \frac{4b - 5t}{\sqrt{bt - t^2}}.$$

Thus, the function of distribution of dark nebulae according to the masses M has the form:

$$S(M) = \frac{a}{5H^5} \cdot \frac{0.8b - M}{\sqrt{bM - M^2}}. \qquad (30)$$

The magnitude of M changes within the interval $M_{min} \leq M \leq M_{max} = 0.8b$.

The numerical values of M_{min} and M_{max} cannot be determined because of lack of knowledge of the coefficient of proportionality k in the equality $M=kpr^2$.

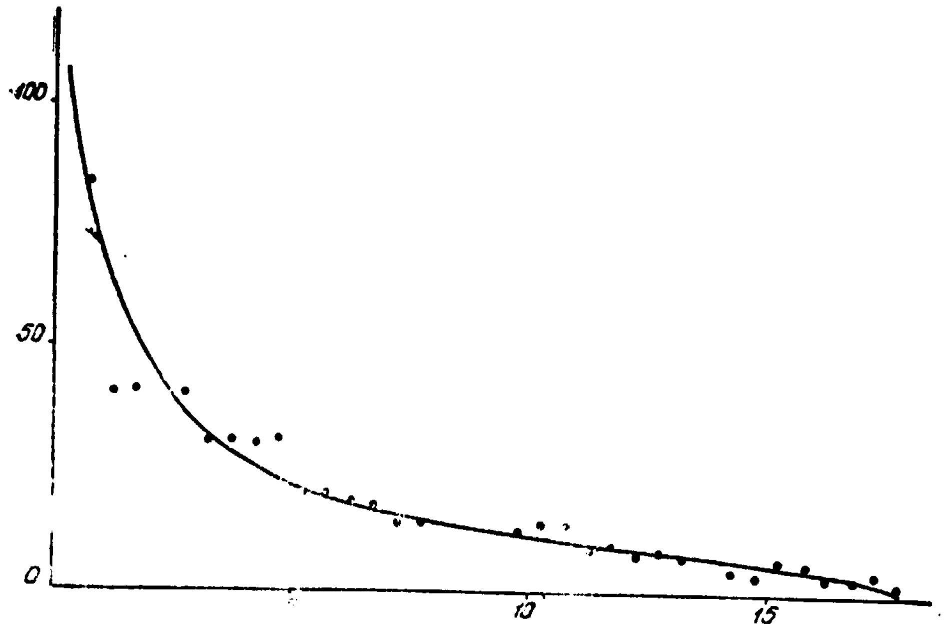

Figure 22

Function (30) is decreasing, i.e. dark nebulae with small masses M are encountered more often than others, and their numbers decrease with an increase in M. If the number 0.8 in formula (30) is rounded up to 1.0, then S(M) and F(p) will have one and the same form.

We would like to emphasize the following circumstance as a conclusion to the present chapter. We constructed all of the distribution function $f(\sigma)$, $\varphi(\Sigma)$, F(p), and S(M) according to the data of observations, or they were obtained by the solution of an equation of stellar statistics. These functions differ little from each other. We were compelled to make some assumptions which simplify the task of revealing the dependence between the different characteristics of dark nebulae. For example, we disregarded dispersions in absolute stellar magnitudes, assumed the proportionality of $\sqrt[3]{V} = \sqrt{\Sigma}$, considered A(M) identical for all of the photographs in Ross's atlas, and others. Therefore, our functions of distribution represent reality with slight approximation. However, the assumptions we made cannot change the nature of the distribution functions, i.e. there should be no doubt that they are all decreasing functions. /109

Basic Results of the Investigation

1. We recorded nearly all of the dark nebulae in the galactic zone presented in Ross and Calvert's atlas. Maps were compiled, according to the photographs in the atlas, on which we drew the outlines of the dark nebulae, the centers, the directions of elongation, and the numbers. All measuring work was done on the maps as well. A tentative catalog of dark nebulae, which we will supplement and expand in the near future, was compiled on the basis of this material. It is possible that we will also be able to publish maps with the outlines of the nebulae. In its present form, the catalog contains the equatorial coordinates α and δ, the galactic coordinates ℓ and b, the apparent surface area σ, the position angle φ, and the statistical weight p. The numbers from Barnard's catalog are given, and some structural features of the nebulae are also noted.

2. a) The apparent shapes of the dark nebulae were studied, and they were grouped according to morphological indicators. The majority of regular dark nebulae have more or less the shape of a regular ellipse of different elongations. With this, a greater value of elongation is observed in the majority of cases in dark nebulae of small dimensions. In addition, dark nebulae of the most diverse shapes are encountered: circular, triangular, polyhedral, formless, filamentous, and others.

b) Dark nebulae were singled out which represent structurally interesting shapes: globules, separate dark filaments, ring-shaped dark nebulae, and others. We established facts which indicate the connection between dark filaments and globules, and suggest the fragmentation of dark filaments into separate globules.

c) Some regions of the Milky Way are indicated, for example in the directions of the constellations Ophiuchi, Orion, Cygnus, Vulpecula, and others, where phenomena are observed which indicate the existence of a connection both between dark nebulae which form separate characteristic groups, and between dark nebulae and nearby bright stars, which is expressed in the coincidence of the direction of orientation of the nebulae with the direction of movement of the star groups.

3. The distribution of the total weight of all of the observed dark nebulae according to the galactic longitude ℓ is characterized by the existence of two maxima in the direction of the center and anticenter of the Galaxy. It is in good agreement with the dependence of the absorption coefficient according to the galactic longitude, according to B. V. Kukarkin. Nebulae located outside of the narrow galactic zone $b=\pm5°$ should be responsible for the appearance of the second small maximum in the direction of the anticenter of the Galaxy. The dark nebulae /110

inside of this zone have only one maximum in the direction of the center of the Galaxy.

4. We determined the position of the plane of symmetry of the system of dark nebulae. The coordinates of the pole of this zone are:

$$A_0 = 186.5°,$$
$$D_0 = +30.6°,$$

and this plane is inclined towards the plane of the Galaxy at an angle

$$i = 4°.$$

This fact supports the asymmetry, indicated by Ye. K. Kharadze, in the distribution of the light-absorbing material with respect to the galactic equator.

5. All of the dark nebulae were divided into two groups according to indicators of their location according to the galactic latitude b. The dark nebulae belonging to group I are located in the narrow galactic zone with latitudes $-5° \leq b \leq +5°$, and all of the remaining nebulae, located outside of this zone, belong to group II. While the dark nebulae in group I in no way stand out from the general apparent structure of the Galaxy and their plan of symmetry coincides with the plane of the Galaxy, the dark nebulae in group II form a separate system, and their plane of symmetry is inclined towards the plane of the Galaxy at an angle of 10.6°. The dark nebulae in groups I and II also differ in the distribution of their total weight according to the galactic longitude.

The position of the pole of the plane of symmetry of the dark nebulae in group II:

$$A_0 = 178°42',$$
$$D_0 = +32°19',$$

is sufficiently close to the pole of Gould's zone. Consequently, first, the reality of the local system is corroborated, and second, the existence of a physical connection between the dark nebulae in group II and the local system seems likely.

6. We studied the distribution of dark nebulae according to the angles of orientation φ, and established that the majority of the dark nebulae are oriented with their elongations parallel

to the plane of the Galaxy, which indicates that the effect of the magnetic field of the entire Galaxy dominates, out of all the possible factors which affect the shape and orientation of dark nebulae.

7. We investigated the functions of distribution of the dark nebulae according to the apparent (σ) and the true (Σ) surface areas, $f(\sigma)$ and $\varphi(\Sigma)$, as well as the function of spatial density $D(r)$.

a) The function $f(\sigma)$ is given by direct measurements. Our material provides the opportunity of carrying out measurements in the interval $0.1<\sigma<\infty$ square degrees. The calculations showed that the number of dark nebulae increases with a decrease in $f(\sigma)$. If we conduct extrapolation for the remaining interval $0<\sigma<0.1$ square degrees, one can think that the curve of $f(\sigma)$ is represented well by an equilateral hyperbola, i.e.

$$f(\sigma) = \frac{C^2}{2\sigma}.$$

b) With respect to the spatial density $D(r)$, it was established that it is impossible to consider the spatial distribution of dark nebulae uniform, i.e. the assumption $D(r)=$ const contradicts the observed facts. The function $D(r)$ also cannot be a monotonically ascending function. The exponential law proposed by P. P. Parenago for the spatial density of dark nebulae, i.e. /111

$$D(r) = D_0 e^{-\frac{r \sin b}{\beta}},$$

does not contradict the data obtained from our material.

c) The function of distribution of the dark nebulae according to the true surface areas Σ, i.e. $\varphi(\Sigma)$, can not have the form $\varphi(\Sigma)=$const, and $\Sigma=$const is also incorrect. Finally, it also cannot be an ascending function. Taking the form $f(\sigma)=C^2/2\sigma$ and $D(r)=D_0 e^{-r \sin b/\beta}$ for the indicated functions, one can determine the function $\varphi(\Sigma)$. It should have the form:

$$\varphi(\Sigma) = \frac{\Sigma_0}{\Sigma}.$$

Consequently, the dark nebulae encountered in the Galaxy are most often of small dimensions.

8. We constructed the function of distribution of the dark nebulae according to the statistical weights p. It has the form

$$F(p)=p_0\sqrt{\frac{\alpha-p}{p}}.$$

9. With respect to the function of distribution of the dark nebulae according to the masses M, i.e. S(M), it was established that it has the form

$$S(M)=\frac{a}{5b^5}\,\frac{0.8b-M}{\sqrt{bM-M^2}}.$$

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